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1,102,041

PATENT SPECIFICATION

DRAWINGS ATTACHED

1,102,041

Date of Application and filing Complete Specification: 4, Feb., 1966.

No. 4980/66.

Complete Specification Published: 7, Feb., 1968.

Index at Acceptance:—B3, D (1D4A1, 1H1X, 1H3, 2A3, 2A8, 2A15, 2A20, 2B1, 2CX, 2F3).

Int. Cl.:—B 24 b 3/48

COMPLETE SPECIFICATION

Automatic grinding method and apparatus.

I, PETER DRUMMOND a British Subject of Northumberland House, 303-306 High Holborn, London, W.C.1., do hereby declare the invention (communicated to me by THE GILLETTE COMPANY, a corporation organised under the laws of the State of Delaware, United States of America, of Gillette Park, Boston, State of Massachusetts, United States of America) for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates generally to control systems and methods and more particularly to a control system and a method for adjusting grinding devices or the like in response to information derived from the surfaces worked upon.

Although the invention is applicable generally to grinding machines and polishing machines in which elongated stock is surface ground or polished as it is moved past rotating abrading devices, it will be described herein for use in connection with the sharpening of razor blade strip.

In making razor blades it is convenient to sharpen a razor blade strip and then cut the sharpened strip into individual blades. The sharpening operation may include one or more grinding operations, a honing operation, and a stropping operation performed sequentially on the blade strip as it is moved along at a predetermined speed. In order to obtain razor blades of uniform shaving quality it is necessary to maintain the included angle of the cutting edges, the widths of the various facets of the bevels, the width of the blades and the location of the central slot within certain predetermined limits. The most critical part of the sharpening operation, insofar as the geometry of the sharpened blade edge is concerned, is the first grinding operation. If this grinding operation is performed accurately, the subsequent sharpening operations can be performed with only infrequent minor corrections. The invention disclosed herein will be described with specific reference to the grinding operation, although it is applicable to all of the sharpening operations involved. The desired half-angle of the ground edge is normally determined by the design of the grinding apparatus and remain substantially constant as long as no structural changes are made therein. Corrective changes in the bevels of the edge and of the width of the sharpened strip can be made by moving the grinding heads in or out on their beds as required, thereby increasing or decreasing the amount of material removed. However, since the blade width is a function of the material removed, adjustments of the grinding heads to change either the relative sizes of the bevels or the width of the strip must correlated.

Skilled grinders can by examination of the finished ground edges of periodically sampled blades detect small deviations from a preset standard and will know from past experience which grinding head or heads should be adjusted, and by how much, in order to bring the blade edge geometry and the width of the blade into correspondence with the standard. As a practical matter, considerable imbalance between the two opposite ground bevels of the edge can be tolerated without affecting the quality of the finished product but by frequently adjusting the grinding heads to balance the bevels (i.e., to make them equal) any drift towards a condition that could affect the quality of the end product can be headed off.

Accordingly, a general object of the present invention is to provide a system and a method for automatically controlling edge forming devices operating on moving

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elongated stock so as to correct for deviations in the geometry of the formed edge from a desired edge geometry.

Another object of the invention is to provide a system and a method for automatically controlling edge forming devices operating on a moving strip so as to correct for deviations from a predetermined desired width and/or half-width of the sharpened strip.

Still another object of the invention is to provide a control system and a method for automatically positioning edge-forming devices operating on a moving strip so as to adjust them simultaneously and in a coordinated manner to provide a predetermined bevel relationship as well as a desired blade width and/or half-width.

A further object of the invention is to provide a control system for scanning the two opposite bevels of a ground edge, comparing the widths of these bevels, producing an error signal as function of the difference in width of these bevels, and automatically adjusting the grinding heads with respect to the blade strip in response to this signal so as to reduce or eliminate the bevel imbalance from which it was derived.

A further object of the invention is to provide a control system for automatically positioning grinding heads operating on a moving metal strip for double-edged blades so as to adjust the grinding heads for a predetermined bevel relationship and a predetermined blade half-width.

A further object of the invention is to provide a control system for detecting certain parameters of a ground strip for double-edged blades, developing error signals as a function of deviations from predetermined parameters and adjusting the grinding devices so as to reduce or eliminate deviations from such predetermined parameters.

A still further object of the present invention is to provide novel means for detecting the width of a bevel of an edge of a ground razor blade strip.

A still further object of the invention is to provide an optical system for periodically scanning a portion of a ground bevel and producing a signal having a time duration as a function of the width of such bevel portion.

Additional objects of the invention will be apparent from the following description of an illustrative embodiment thereof.

The invention accordingly comprises the apparatus having the construction, combination of elements and arrangement of parts, and the method comprising the several steps and the relation of one or more of such steps with respect to others, which are exemplified in the apparatus and method hereinafter described and illustrated in the accompanying drawings wherein like reference numbers designate like parts, and in which:

Fig. 1 is a block diagram of the entire system;

Fig. 2 is a view in side elevation of the bevel scanner unit with portions of the housing broken away;

Fig. 3 is a plan view of the bevel scanner with the cover removed;

Fig. 4 is an end view of the microscope tube taken on line 4-4 of Fig. 3;

Fig. 5 is a cross-section view of the microscope adjusting mechanism taken on line 5-5 of Fig. 2;

Fig. 6 is a schematic representation of the optical system of the scanner;

Fig. 7 is a view in side elevation of the half-width detector assembly;

Fig. 8 is a view in front elevation of the half-width detector;

Fig. 9 is an enlarged view in side elevation of the blade strip supporting unit;

Fig. 10 is an enlarged fragmentary isometric view, partly in section, of the blade strip supporting unit;

Fig. 11 is a diagram of the photo detector and amplifier circuit;

Fig. 12 is a circuit diagram of the pulse width detector and amplifier unit;

Fig. 12A shows waveforms that illustrate the operation of the pulse width detector of Fig. 12;

Fig. 13 is a circuit diagram of the phase sensitive detector and amplifier unit;

Fig. 14 is a circuit diagram of the programmer;

Fig. 15 is an isometric, partly exploded view illustrating the general construction of a meter relay;

Fig. 16 is a timing diagram of cam operated contacts that control the operation of the programmer;

Fig. 17 is a grinding head correction chart;

Fig. 18 is a schematic diagram of a pulse train generating unit;

Fig. 19 illustrates the phase relationship between two pulse trains applied to respective field windings of a motor that positions a grinding head;

Fig. 20 is a view in side elevation, partly in section, of a grinding head assembly;

Fig. 21 is a plan view of a grinding head assembly;

Fig. 22 is a view in front elevation of the grinding head assembly; and

Fig. 23 is a plan view of a grinding machine illustrating the positions of the bevel scanners and the half-width detectors with respect to the grinding heads.

GENERAL DESCRIPTION

The grinding system in accordance with

the invention is shown in block form in Fig. 1. Generally speaking, the system operates on the zero-seeking principle. It senses the bevels and the width of a moving sharpened razor blade strip and determines deviations from bevel balance or some other desired bevel relationship and deviations of the blade half-width from a predetermined standard; it decides from this determination what correctional movements are needed by the grinding heads of the machine in order to reduce the deviations to zero; and it then actuates the grinding heads to accomplish those movements.

For the purpose of illustrating the nature of the invention, a specific embodiment of the invention will be described as it pertains to the grinding of the four bevels of a moving razor blade strip for double-edged razor blades; but it will be obvious to those skilled in the art that the invention has wide applications in the field of material removal and is not limited to the specific utilization illustrated. Thus, the invention is applicable to the formation of sharpened edges such as by grinding, honing, stropping or by other means and is particularly applicable to the formation of edges on razor blade strips.

In the following description of the invention, it will be assumed that a razor blade strip 10, Fig. 1, is moving toward an observer. The two top bevels will be referred to as bevels 1 and 3 and the two bottom bevels as bevels 2 and 4. The distance measured from the upper edge of the center slot to the apex formed by the bevels 1 and 3 of the blade strip will be referred to as the top half-width, and the distance from the lower edge of the center slot to the apex formed by the bevels 2 and 4 will be referred to as the bottom half-width. The grinding head that grinds bevel 1 will be referred to as grinding head 1 and the grinding head that grinds bevel 2 as grinding head 2 and so on.

Referring now to Fig. 1 for a general description of the system illustrated therein, optical scanners 11 and 12 are associated with the top bevels 1 and 3, respectively, of the blade strip 10 and generate electrical signals as a function of the widths of the respective bevels scanned. The signals derived from the scanners 11 and 12 are, respectively, amplified in amplifiers 13 and 14, modified and amplified in pulse width detectors and amplifiers 15 and 16, clipped and integrated in clippers and integrators 17 and 18, and the integrated signals are amplified by d.c. amplifiers 19 and 20. The d.c. potentials from the amplifiers 19 and 20 are compared by a meter relay 21 and by a visual meter 22. A blade half-width measuring device 23 develops a.c. error signals as a function of the sense and magnitude of deviations of the top half-width of the blade strip 10 from a predetermined standard 24, which signals are amplified by an amplifier 26 and converted into a corresponding d.c. error signal by a phase sensitive detector 27, and the resulting d.c. error signal is amplified by an amplifier 28 and applied to a meter relay 30 and a visual meter 31. A system which may be an exact duplicate of that operating on the top half of the blade strip operates on the bottom half thereof with the exception of the meter relays 21 and 30 which are used alternately for both systems. The outputs from the meter relays 21 and 30 are applied to a programmer 32, the output of which is connected to grinding head controls 34, 35, 36 and 37 which actuate grinding head displacing devices in accordance with a correction sequence determined by the programmer.

The optical scanner 11 associated with bevel 1 scans this bevel successively from a predetermined point along the bevel as determined by a fixed mask to and beyond the heel (where the ground edge starts), and produces raw electrical signal pulses each of which has a detectable portion proportional to the width of the portion of the ground bevel scanned. These raw signal pulses are operated upon in the pulse width detector and amplifier 16 which produces amplified square wave pulses corresponding in width to the detectable portions of the raw pulses. These square wave pulses are clipped to an exact predetermined amplitude and then integrated to produce a d.c. potential which is the average of the width-potential product of a series of such pulses. This d.c. potential is amplified by a d.c. amplifier 20 and applied through a double-pole, double-throw, cam-operated switch 40 to one side of the meter relay 21. The bevel 3 of the blade strip is similarly scanned by the optical scanner 12 and the signals derived from this scanner are operated upon as described above in connection with signals derived from the scanner 11 to produce a d.c. potential at the output of the d.c. amplifier 19 proportional to the distance between the heel of the ground bevel 3 and the cut-off point provided by the scanning mask, which d.c. potential is applied to the other side of the meter relay 21. The cut-off points of the scanning mask of the two scanners 11 and 12 are so adjusted that when a blade strip is scanned in which bevels 1 and 3 are in exact balance, pulses of exactly the same width are produced at the outputs of the pulse width detectors and amplifiers 15 and 16. Similarly, the d.c. amplifiers 19 and 20 are so adjusted that the output

potentials therefrom are exactly equal when the bevels 1 and 3 are in exact balance. It will be assumed herein that the visual indicating meter 22 and the meter relay 21 will be deflected in a positive sense when the bevel 3 is larger than the bevel 1 and in a negative sense when the bevel 1 is larger than the bevel 3.

A deflection of the meter relay 21 in either positive or negative sense indicates that a corrective positioning is required of the grinding heads operating upon the bevels 1 and 3 so as to bring the bevels into balance. However, any change in the position of one or the other of the grinding heads 1 and 3 will result in a change in the half-width of the blade, so that the size of the half-width of the blade must also be taken into account in the determination of the grinding head movements required in order to correct for the bevel imbalance indicated. To this end the half-width detector 23 is provided, which generally comprises a differential transformer actuated by a sensing element engaging the top edge of the blade strip 10 operating in conjunction with a reference device 24, which may be a similar differential transformer, to produce output signals of a polarity indicating whether the blade half-width is too large or too small with respect to a predetermined "target" and of an amplitude indicating the amount of deviation therefrom. The signals from the half-width detector 23 and the reference device 24 are amplified by the amplifier 26 and detected by the phase sensitive detector 27, and the resulting signals from the detector are applied to a differential d.c. amplifier 28 which produces a difference in d.c. potential on two output leads of a polarity and potential reflecting the sense and magnitude of the deviation of the measured half-width from the target. The visual indicating meter 31 and the meter relay 30 will be deflected in a positive sense when the top half-width of the blade is too large and a negative deflection when the top half-width is too small.

The programmer 32 selects appropriate correction sequences from a predetermined program in accordance with the deflections of the meter relays 21 and 30 and transmits the appropriate directions to the grinding head controls 34 and 35 that will effect the positioning of the grinding heads 1 and 3 to correct any imbalance between the ground bevels 1 and 3 and at the same time correct for any blade half-width deviation. After having completed the sampling of the error signals derived from the top half of the blade strip, the programmer operates the switches 40 and 42 to disconnect the d.c. amplifiers 19 and 20 from the meter relay 21 and connect thereto the corresponding d.c. amplifiers 44 and 46 associated with the bevels 2 and 4, respectively, and disconnect the d.c. amplifier 28 from the meter relay 30 and connect thereto the corresponding d.c. amplifier 48 associated with the bottom half-width detector 50. The meter relay 21 will now respond to the bevel balance error signals derived from the bevels 2 and 4 and the meter relay 30 will respond to the bottom-half-width error signals. The programmer 32 now selects the appropriate correction sequences for the grinding heads 2 and 4 sends the appropriate directions to effect the necessary corrections to the grinding head controls 36 and 37, after which the programmer will again operate the switches 40 and 42 to transmit directions to controls 34 and 35 and so on. The programmer 32 will thus alternately sample signals derived from the top of the blade and from the bottom half of the blade and effect the grinding head corrections required. The timing of the system is such that the portion of the blade strip that is ground by the grinding heads after the grinding head corrections have been made reach the bevel balance scanners and the half-width detector before the next sample is taken. The entire system is adjusted so that the correction set into the grinding heads will not over-correct for the errors detected in the blade strip geometry but will always tend to reduce such errors to zero. Means is provided, which will be described hereinafter, which will reduce the amounts the grinding heads are moved in response to directions from the programmer 32 so as to prevent any over-correction, and, hence, prevent any tendency of the system to "hunt" or oscillate.

BEVEL SCANNERS

The four optical scanners associated with the respective bevels of the ground razor blade strip may be identical in their operating principles and are mounted so that the axis of each scanner is substantially normal to the plane of the ground bevel with which it is associated. The optical scanner 11 associated with bevel 1 is shown in Figs. 2 and 3 together with a portion of the diametrically opposite scanner 12 associated with bevel 3.

Each scanner includes a source of light 100, which directs a concentrated beam of light onto the freshly ground bevel with which it is associated, a microscope 102 disposed so as to cover the portion of the ground blade bevel that includes the heel (where the ground edge starts), a scanning mechanism 104 and a phototube detecting and amplifier unit 106.

The microscope 102 includes an objective 110, Fig. 3 threaded into the end of a metal tube 112, and an eyepiece 114 threaded into the opposite end of the tube. The microscope tube 112 is received within a rigid outer tube 116 and is adjustably secured thereto by means of a clamp ring 118 which embraces a split end 120 of the tube 116. The clamping tube 116 is pivotally mounted in a yoke 122 of a microscope supporting bracket 124 by means of a collar 126 supported in the yoke by pivot pins or trunnions 128.

In order to permit the microscope to be adjusted in elevation, there is provided an adjusting mechanism that includes a yoke 130 supported on an eccentric shaft 132, Fig. 5. The tube 116 is held in the yoke 130 by means of a collar 134 pivotally mounted in the yoke by pivot pins 135. A downwardly extending neck 136 of the yoke is received between a pair of ears 138 and 139 on the bracket 124 in which the eccentric shaft 132 is journaled. The eccentric shaft 132 includes an expanded hub 140 received within the ear 138 and a reduced hub 142 that extends through and beyond the ear 139 and has a spur gear 144 rigidly secured thereto by means of a nut 146 screwed onto the outer threaded end thereof. It will be appreciated that as the eccentric shaft 132 is rotated by rotation of the gear 144 in one direction or the other the yoke 130 and hence the end of the tube 116, attached thereto will be moved upwardly or downwardly. A worm gear 148 (Fig. 2) is rotatably mounted in journals 150, which may be formed integrally with the microscope bracket 124, and the operating shaft 151 therefor extends upwardly and terminates in a finger knob 152 by which the worm gear 148 can be manually rotated in one direction or the other.

A ratchet wheel 154 secured to the shaft 151 and a ratchet spring 156 mounted on the bracket 124 are provided for maintaining the worm gear in its set position. The bracket 157 for supporting the light 100 may conveniently be mounted on the side of the bracket 124 by means of a mounting screw 158.

The tube 116 extends through an opening 160 in the microscope housing 162 and supports the housing 164 of the scanning mechanism 104 and the housing 165 of the phototube detecting unit 106. The housing 164 is securely and rigidly clamped to the tube 116 by means of a pair of set screws 166. The opening 160 is sufficiently large to accommodate the necessary adjustments of the microscope. The tube 116 is provided with a transverse slot 170 (Fig. 3) near the outer end thereof for receiving the peripheral portion of a rotating scanning disc 172. A mask 174 having an aperture 175 of a shape shown in Fig. 6 is fitted within the end of the tube 116 to limit the light reflected from the bevel being scanned to a predetermined portion of the bevel. The mask 174 is cemented to an end piece 176 secured into the end of the tube 116 by a set-screw. The scanning disc 172 is rigidly mounted on the drive shaft 177 of an induction motor 178 and is provided with a plurality of equally spaced radial slots 180 (Fig. 6). The phototube detecting unit 106 mounted within the housing 165 includes a phototube 181 which may suitably be a photo-multiplier tube such as type 931A, manufactured and sold by R.C.A., Camden, New Jersey.

The aperture 175 of the mask 174, (Fig. 6), transmits the image of the sharpened bevel 1 magnified by the objective 110 and eyepiece 114, starting at a certain point between the heel 182 of the bevel and the ultimate edge and extending to a point well below the heel. The flank of the razor blade strip reflects far less light into the scanner than the freshly ground bevel surface and as a slot 180 in the scanner disc 172 sweeps across the opening 175 in the mask, a sharp increase in the light intensity is transmitted throug the slot as soon as it encounters the image and a drop in light intensity occurs when the slot passes the line of demarcation (referred to above as the "heel") in the image between the ground surface of the blade strip and the flat flank thereof. This sharp decrease in the light intensity is used in accordance with the present invention to indicate the time at which the slit passes the heel of the ground surface. The aperture 175 in the mask 174 is formed with a taper at the bottom to prevent the transmitted light from being shut off with sufficient abruptness to cause a spurious response in the detecting circuit. If equal bevels are desired, the scanning units associated with the bevels 1 and 3 are adjusted while scanning a test blade having balanced bevels. The two scanning units are adjusted by turning the finger knobs 152 to either raise or lower the microscopes as required until the light reflected from the bevels is transmitted through the opening 175 of the mask 174 of each unit for exactly the same period of time. The two microscopes are thus set to a certain predetermined standard bevel balance to which it is desired to bring the bevels of a sharpened razor blade strip being sampled by the two scanning devices. A sharpened razor blade strip moved past the oppositely mounted scanning units will, if the ground bevels balance exactly, cause the reflected light from the ground bevels to be transmitted through the slots 180 of the scanning discs 172 for

exactly the same proportion of the total cycle. Since the duty cycle, i.e., the mark-to-space ratio of the pulse pattern, is a quantity which is established uniquely by the distance between the top of the opening 175 in the mask 174 and the image of the heel on the one hand and the spacing between the successive slots 180 of the disc 172 on the other hand, the speed of the disc is not important. A change in the speed of the discs would only result in a narrowing or widening of the entire pulse pattern which would not affect the integrated value of the pulses. Since only the mark-to-space ratio of the pulses is measured, the only requirement for proper operation is that sufficient reflected light is obtained to produce a signal across the output of the phototube that has a detectable rise in level as the slot 180 in the disc 172 enters the opening 175 of the mask 174 and a detectable drop when it passes from the ground edge of the razor blade onto the flank thereof. By masking the edge of the razor blade, errors which might result by scanning the ragged raw edge of the freshly rough ground blade are avoided. It will be appreciated that the two scanners in effect determine whether the two heels of the two bevels being compared are at the exact same level, and since each of the grinding heads grinds the bevels at a predetermined equal angle with respect to the central plane of the razor blade strip, the bevel widths will be exactly alike as long as the heels thereof are perfectly aligned. Variations in intensity of the transmitted light caused for example by variations in the reflectivity of the ground edges, by dirt, grime and cutting oil thereon or by an oil film or particles adhering to the objective 110 or by variations in photomultiplier or amplifier sensitivity will not adversely affect the effectiveness of the scanner as long as the transmitted light is above a certain minimum level.

The microscope bracket 124 of the scanner 11 for bevel 1 and the corresponding bracket of the scanner 12 for bevel 3, may be supported by a base 183, Fig. 2, which is suitably supported on the bed of the machine itself such as by spanning a pair of rails 184 running on each side of the machine lengthwise thereof and parallel to the movements of the razor blade strip. The common housing 162 for the two microscope units 102 is provided with a cover 163 that prevents entry of undesired light which, if modulated, might cause spurious signals, and further prevents outside dirt and fumes from entering the enclosure while permitting access to the finger knobs 152 for adjusting the microscopes whenever necessary.

Secured to the base 183 between the bevel scanners 1 and 3 is a blade strip supporting bracket 185, Figs. 7 and 8, which also serves to support the half-width detector 23. The bracket 185 is provided with a side recess 186 for receiving a blade strip supporting structure 187, and with a horizontal rail 188 within the recess for supporting the half-width detector 23. The half-width detector 23 includes a block 189 resting on the rail 188 and bolted to the bracket 185 and having a horizontal channel 190 formed adjacent the lower edge thereof. The block 189 is recessed to receive a plate 191 having a channel 192 complementary to the channel 190 in the block. The bottom edges of the block 189 and the plate 191 are spaced by a distance sufficient to permit the blade strip 10 to pass therebetween. The plate 191 may suitably be bolted to the block 189. A carbide key 194 is loosely confined within the enclosure defined by the channels 190 and 192 and rides on the top edge of the razor blade strip 10. The top surface of the carbide key 194 is provided with a centrally located recess 196 which forms a shoulder 197 on each side of the block 189 that retain the key in position and prevent it from longitudinally following the moving razor blade strip 10 on which it is resting. A further recess 198 is provided in the bottom surface of the carbide key 194 at the location of the optical scanners so as to expose the blade strip bevels thereto. Extending downwardly from the top of the block 189 and centrally located therewithin is a bore 199 through which extends a pin 200 resting on the top surface of the carbide key 194. The top surface of the block 189 is provided with a well 201 centered with respect to the bore 199 and adapted to receive a differential transformer 202. A movable core 203 of the transformer 202 is threaded onto the pin 200 and a second pin 204 is threaded into the top of the core 203 and terminates in a shouldered spring abutment 205 for receiving the end of a compression spring 206 contained within a U-shaped bracket 207. The other end of the spring 206 is received by an abutment 208 formed at the end of a spring adjusting plug 209 threaded into the end of the bracket 207.

The blade strip supporting structure 187 includes a supporting block 210 received within the recess 186 of the bracket 185 at the bottom end thereof and rigidly secured thereto by means of bolts 211. Integrally formed on the block 210 is an upwardly extending wedge 212 that carries blade strip supporting plates 214 and 215 on the respective wedge surfaces thereof. The plates 214 and 215 are secured to the respective inclined wedge surfaces by means

of bolts 216 extending through the wedge 212 and through elongated openings 218 in the plates 214 and 215 which permit limited vertical adjustments thereof. The upper ends of the plates 214 and 215 are spaced apart by a distance sufficient to permit a blade strip to move therebetween. The plate 214 is provided with a longitudinally extending groove 217 (Figs. 9 and 10) and seated within a channel 219 of the plate 215 is a key 220 that extends part way into the groove 217 of the plate 214. The key 220 is tapered at both ends. The spacing between the key 220 and the bottom of the groove 217 is sufficient to permit the joined sections of the razor blades strip between the central slots therein to bend around the key 220 as shown in Fig. 10. The portions of the razor blade strip adjacent the slots will not, however, bend around the key 220 but the lower edges of the upper portions will rest on the top flat surface thereof. It will thus be appreciated that as the razor blade strip is moved through the spacing between the plates 214 and 215 the lower edges of the razor blade strip immediately above the central slots will rest upon the top surface of the key 220 while the joined portions of the strip between the slots will bend around the key within the groove 217 of the plate 214. The carbide key 194 biased downwardly by the spring 206 will press the razor blade strip firmly against the top surface of the key 220.

The razor blade strip holder 187 supports the moving blade strip 10 in such a position that the sharpened edge thereof will be disposed at all times between the two channels 190 and 192 in the block 189 and the plate 191, respectively, whereby the carbide key 194 will always engage and ride on top of the sharpened edge of the strip.

PHOTOTUBE AMPLIFIER AND PULSE WIDTH DETECTOR AND AMPLIFIER

A circuit for converting the variations in the intensity of the light beam passing through the slots 180 of the scanning disc 172 into corresponding electrical signals is illustrated in Fig. 11. The phototube 181 which may suitably be a 931-A type tube such as manufactured by R.C.A., Camden, New Jersey, is connected as shown and as recommended by the manufacturer. The output signal from the phototube 181 appears across a resistor 222 connected between the tenth and last plate 224 and ground. The output signal across the resistor 222, which signal has a time duration equal to the time it takes the scanner to sweep across the exposed portion of the blade strip edge being sampled, is applied to the input of an amplifier tube 226 of the amplifier 14 through a coupling capacitor 227 and the output from the amplifier tube 226 is connected to the grid of a second amplifier tube 228 through a coupling capacitor 229 and a potentiometer 230. The amplitude of the output signal from the amplifier tube 228 appearing on the output terminal 232 and applied to the input of the pulse width detector and amplifier 16 (Fig. 12) can be adjusted by adjusting the slider of the potentiometer 230.

The raw signal pulse 240 (Fig. 12) appearing on the terminal 232 and derived from the optical scanner and the phototube detecting and amplifier circuit (Fig. 11) is a negative-going one having a time duration between the sharply falling edge 244 and the sharply rising edge 245 thereof proportional to the width of the portion of the bevel scanned, i.e. the portion between the point at which the reflected light enters the opening 175 of the scanner mask 174 (Fig. 6) and the heel 182 (where the ground surface starts). The amplitude of these pulses may vary due to inherent changes in reflectivity of the freshly ground surface or the sensitivity of the scanner, but variations in the amplitude of successive signals from one scanner or of signals derived from different scanners are not a problem so long as the pulses are of sufficient amplitude to permit the time duration thereof to be detected.

The differential amplifier 16 is adapted to produce essentially square-sided amplified pulses having a time duration equal to the time duration between the sharply falling and rising edges 244 and 245 of the raw input pulse 240, thereby cutting off the trailing portion 246. The differential amplifier includes a pair of tubes 250 and 251, which may be the two halves of a double triode, having the cathodes thereof connected to ground through a common cathode resistor 252. The plate of the tube 250 is connected to a d.c. line 254 through a load resistor 256 while the plate of the tube 251 is connected directly to the d.c. line. The input pulses 240 are applied to the grid of the tube 250 through a coupling capacitor 257 and a resistor 258. The grid of the tube 250 is connected to the grid of the tube 251 through a resistor 259 shunted by a diode or rectifier 260. The juncture between the coupling capacitor 257 and the resistor 258 is connected through a resistor 261 to a positive potential conveniently provided at the juncture 262 between resistors 263 and 264 connected in series across the d.c. line 254 and ground. The grid of the tube 251 is connected to the positive juncture 262 through a storage capacitor 265.

For a better understanding of the operation of the detector and amplifier circuit 16, reference is made to Fig. 12A wherein the signal waveform 240 appearing at the juncture 266 and the waveforms 267 and 269 appearing at the grids of the respective tubes 250 and 251 are shown superimposed above the resulting waveform 271 that will appear at the plate of the tube 250. The potential at the grid 250 will be positive with respect to the potential at the grid 251 just before a signal pulse is applied to the terminal 232 after the circuit has been in operation for a sufficient length of time to become stabilized.

The descending steep portion 244 of the signal waveform 240 (representing an input pulse) will drive the grid of the tube 250 to the same potential as the grid of the tube 251 and this sudden differential change in potential of the two grids will result in a sharp rise in plate potential as shown in the waveform 271 representing the output pulse. The plate potential of the tube 250 will thereafter remain at a substantially constant value as long as the potentials at the two grids are equal to each other, which is a characteristic of differential amplifiers well known to those skilled in the art.

The potentials at the grids of the tubes 250 and 251 will not follow the descending portion 244 of the waveform 240 because of the capacitor 265 which discharges through the diode 260 and the resistors 258 and 261 but will go negative more slowly at a rate determined by the values of the resistor 258 and the capacitor 265 in accordance with the well known law applying to resistance-capacitance circuits. Since the impedance of the diode 260 to current flow (conventional) from the capacitor 265 to the resistor 258 is negligible, the potentials at the grids of the tubes 250 and 251 will be substantially equal during this descent and hence no change will occur in the plate potential of the tube 250. Transients indicated at the bottom of the wave 340 will have no effect on the output signal as long as they do not rise above the potentials at the grids of the tubes 250 and 251.

The ascending portion 245 of the waveform 240 will cause a current flow to the capacitor 265 through the resistors 258 and 259 when it rises above the potentials at the grids of the tubes 250 and 251 and a difference in potential equal to the voltage drop across the resistor 259 will be developed thereacross resulting in a sudden conduction of the tube 250 to drop the potential on the plate thereof, as indicated in the output pulse 271.

It will be appreciated that the width of the squared portion of the output pulse 271 will correspond to the width of the input pulse 240 between the steeply descending portion 244 and the steeply ascending portion 245 as long as the values of the capacitor 265 and the resistor 258 are selected so that the slowly descending portions of the waveforms 267 and 269 intercept the steeply ascending portion 245. If these descending portions descend too rapidly they might be intercepted by transients at the bottom of the waveform 240 to cause the tube 250 to conduct prematurely and if too slow they might be intercepted by the trailing portion 246 instead of the ascending portion 245 to make the output pulse too long.

The output pulse 271 at the plate of tube 250 is applied to a network consisting of a capacitor 272 and a resistor 273 in series, the values of the capacitor and the resistor being so chosen that the waveform 271 appears substantially unchanged at the juncture of the capacitor 272 and the resistor 273. This juncture is connected to one grid of tube 268, the cathodes of which are returned directly to ground. This connection effectively limits the positive excursion of waveform 271 appearing at the grid of tube 268 to ground potential. It will be appreciated that the potential at the grid of tube 268 will therefore be sufficiently negative to cut off the plate current of tube 268 except during the interval between the steeply ascending portion of waveform 271 and the steeply descending portion thereof, and that during the said interval the plate current will remain substantially constant. This results in the amplified and inverted replica 270 of the topmost portion only of waveform 271 appearing at the plate of tube 268.

The amplified negative output pulse 270 from the tube 268 is applied to a pulse clipping network that includes a coupling capacitor 281 and a resistor 274 connected in series to a terminal 275 which is connected to ground through a rectifier 276, and through a rectifier 280 and a resistor 282 connected in parallel to a positive potential conveniently provided at the juncture 277 between resistors 278 and 279 connected in series across the d.c. line 254 and ground. The terminal 275 is connected to the grid of a d.c. amplifier tube 284 of the amplifier 20 through a resistor 286 which forms an integrating circuit with a capacitor 287 connected between the grid of the tube 284 and ground. The rectifier 276 is poled so as to conduct when the potential at the terminal 275 tends to go below ground potential and the rectifier 280 is poled so as to conduct when the potential at this terminal tends to go more positive than the juncture 277.

The approximately square wave 270

from the amplifier 16 is of sufficient amplitude to tend to drive the terminal 275 above the positive potential of the juncture 277 and below ground potential, but since the rectifiers 276 and 280 are poled so as to limit the excursions of this terminal to these potentials, a square wave 288 of an exact, predetermined amplitude will always appear on this terminal.

The raw signal pulse similar to the pulse 240 derived from the scanner 12 which operates on the opposite bevel 3 of the blade strip 10 is applied to the input of the differential amplifier 15 which preferably is identical with the differential amplifier 16 described above. The output pulse from the amplifier 16 is connected to a terminal 289 through a capacitor 290 and a resistor 291 and the terminal 289 is connected to ground and to the positive juncture 277 through rectifiers 292 and 293 respectively. The terminal 289 is connected to the grid of a d.c. amplifier tube 294 of the amplifier 19 through a resistor 296 and a capacitor 297 is connected between the grid of the tube 294 and ground. The clipper and amplifier circuit comprising the elements 289 to 293 is made identical with the clipper and amplifier circuit 272 to 282 in order to provide symmetrical conditions.

The resistor capacitor combinations 286, 287 and 296, 297 constitute integrator networks in which the resistors may suitably be of about 1 megohm and the capacitors of about 2 microfarads. The potential developed across each capacitor 287 and 297 and applied to the grid of the associated tube 284, 294 will be proportional to the ratio of the average width of the significant portions between the edges 244 and 245 of the pulses 240 derived from the scanners 11 and 12 to the duration of the entire cycle. The load resistor 298 of the tube 284 and the load resistor 299 of the tube 294 are connected to the opposite ends of a potentiometer 300 whose slider is connected to the d.c. line. The cathodes of the tubes 284 and 294 are connected to ground through a common cathode resistor 302.

The potentiometer 300 is adjusted so that the d.c. potentials on the plates of the tubes 284 and 294 are equal when the pulses from the differential amplifiers 15 and 16 are derived from exactly balanced bevels. In order to initially set the circuit shown in Fig. 12, a test blade whose bevels are exactly in balance is placed in front of the scanners and the potentiometer 300 is adjusted until the outputs from the tubes 284 and 294 are exactly equal. When now a blade strip whose adjacent bevels are out of balance is scanned, the pulses sent to the intergrating circuits 286, 287 and 296, 297 will be of different widths which will be reflected in the potentials on the capacitors 287 and 297 and hence in the d.c. potentials appearing on the output terminals of the d.c. amplifier tubes 284 and 294. The d.c. output terminals of the tubes 284 and 294 are applied to the opposite ends of the deflection coil of the meter relay 21 and will result in a deflection of such meter in accordance with the sense and degree of bevel imbalance. It will be recalled that for the purposes of description it was assumed that the d.c. outputs from the tubes 284 and 294 will deflect the meter relay 21 in a positive sense when bevel 1 is too small or narrow with respect to bevel 3 with which it is compared and in a negative sense when bevel 3 is too small with respect to bevel 1.

The signal pulses derived from the bevels 2 and 4 are detected, amplified, clipped and integrated by circuits preferably identical with those described above in connection with the pulse derived from the bevels 1 and 3. The integrated potentials are amplified by amplifiers 44 and 46 (Fig. 1) identical with amplifiers 19 and 20 and the output potentials therefrom are compared in a meter relay which, in the apparatus described herein, is the same meter relay 21 that compares signals derived from the bevels 1 and 3.

HALF-WIDTH DETECTOR AND COMPARATOR

As described above in connection with Figs. 9 and 10, the blade strip 10 runs through a supporting structure 185 which supports the strip by the center slots, and the carbide key 194 which is pressed against the sharpened blade strip edge by the spring 206 moves up or down in accordance with variations in the half-width of the strip. The key 194 is connected to the core 203 of the linear variable differential transformer 202 and the position of the key with respect to the physical assembly as a whole is reflected in an electrical signal at the output of the transformer. When the core is centered in the transformer no output signal will appear across the output terminals of the transformer, indicating that the blade half-width is on "target". When the core is above the center position, an alternating signal of one phase will indicate that the blade half-width is too large, and when the core is below the center position, an alternating signal of the opposite phase will indicate that the blade half-width is too small. Since the amplitude of the error signals increases as the core moves away from the center position, the output signal from the differential transformer will indicate by phase and by amplitude the position of the carbide key and hence the half-width of the blade strip with reference to a predetermined

standard.

Referring now to Fig. 13, the differential transformer 202 comprises an input winding 310, a pair of differentially connected output windings 312 and 313, and the core 203 connected to the carbide key 194 which is shown riding on the top edge of the moving sharpened blade strip 10. The upper terminal of the winding 313 is connected to ground, and the lower terminal is connected to the lower terminal of the winding 312, the upper terminal of which is connected through an isolating resistor 314 to the input 315 of a two stage amplifier 316. Also, connected to the input 315 of the amplifier 316 through an isolating resistor 318 of the same resistance as the resistor 314 is the output from a second differential transformer 320, which serves as a reference for the differential transformer 202 and which may be identical therewith except that the movable core 322 thereof is arranged for manual adjustment by means of a finger knob 328 mounted on the end of a micrometer stem 326 passing through an internally threaded micrometer mount 325 and secured to the core 322. An indicating dial 324 is provided below the knob 328 and the core 322 may be adjusted upwardly or downwardly as desired by turning the knob. The input winding 310 of the transformer 202 and the input winding 330 of the compensating transformer 320 are energized from a common source 332 of 5000 cycle alternating current.

The output signal from the amplifier 316 is applied to a second two stage amplifier 334 through a band-pass filter comprising a capacitor 336 connected to ground through a branched network comprising a resistor 337 connected in parallel with series connected resistor 338 and capacitor 339. The capacitors 336 and 339 and the resistors 337 and 338 of the band-pass filter are chosen so as to provide a response curve that will peak at approximately the frequency used to excite the differential transformers, in this case 5000 cycles per second. To this end, the capacitors 336 and 339 may have the values of 820 and 40 micro-microfarads, respectively, and the resistors 337 and 338 the values of 100,000 ohms and 91,000 ohms, respectively. This band-pass filter will thus reject higher and lower frequencies that, if present, might interfere with the operation of the subsequent circuits. The juncture between the resistor 338 and the capacitor 339 is connected to the input of the amplifier 334. The plate of the tube 340 of the second stage of the amplifier 334 is connected to the d.c. line 342 through the primary winding 344 of a transformer 345 and a resistor 346. The juncture between the resistor 346 and the primary winding 344 is connected to ground through a by-pass capacitor 347 which also serves as a ripple filter.

The transformer 345 is provided with a pair of secondary windings 348 and 349, the outside terminals of which are connected to the plates of a pair of tubes 351 and 352, respectively, arranged to function as gated diodes. The cathodes of the tubes 351 and 352 are grounded and the grids thereof are connected through the respective resistors 353 and 354 and a common phase shift net work 356 to the source 332 of 5000 cycle alternating current. The inside terminals of the secondary windings 348 and 349 are connected to ground through respective high frequency by-pass capacitors 357 and 358. The inside terminal of the secondary winding 349 is also connected to a d.c. amplifier tube 360 through an integrating network comprising a resistor 361 and capacitor 362, the latter being connected between the grid of the tube and ground. The capacitor 362 is shunted by a bleeder resistor 363. The inside terminal of the secondary winding 348 is similarly connected to the input of a d.c. amplifier tube 364 through an integrating network comprising a resistor 366 and a capacitor 367, the latter being connected between the grid of the tube and ground. The capacitor 367 is shunted by a bleeder resistor 368. The resistors 361, 363, 366 and 368 may suitably have a value in the order of 1 megohm and the capacitors 362 and 367 may suitably have a value in the order of 2 microfarads.

The cathodes of the d.c. amplifier tubes 360 and 364 are connected to ground through a common cathode resistor 370, and the plates thereof are connected to the opposite sides of a potentiometer 372 through resistors 374 and 375, respectively, the slider of the potentiometer being connected to the d.c. line 342. The output terminals of the tubes 360 and 364 are connected to opposite ends of the deflection coil of the meter relay 30 and the slider of the potentiometer 372 is adjusted so as to cause zero deflection of the meter when no signal appears across the primary winding 344 of the transformer 345.

The differential transformer 202 is initially mounted with respect to the blade strip 10 so that it will produce no output when the carbide key 194 rests on a sharpened blade strip 10 which is of exactly the desired half-width. If the half-width of the blade strip should deviate from the desired standard or "target", the core 203 of the transformer will be displaced upwardly with respect to its neutral or central position if the half-width is too large and will drop downwardly from the central position if the half-width is too

small. With the core 203 disposed in the central position indicated, equal and opposite potentials will be induced across the secondary windings 312 and 313 which will cancel each other and no signal will be applied to the amplifier 316. If the half-width of the blade strip 10 increases and thereby causes the core 203 to move upwardly, a better coupling is provided between the primary winding 310 and the secondary winding 312 than between the primary winding and the secondary winding 313 and hence an output signal predominantly from the output winding 312 will be generated in the output of the transformer and applied to the input of the amplifier 316. However, if the half-width of the strip decreases and causes the core 203 to move downwardly to provide a better coupling between the primary winding 310 and the secondary winding 313 than between the winding 310 and the secondary winding 312, an output signal predominantly from the output winding 313 phased oppositely to that from the winding 312 and hence poled oppositely to the signal generated when the core was in an elevated position, will be applied to the amplifier 316. Within the limits of operation, the further the core is moved away from its central position, the larger will be the output signal. The signal applied to the amplifier 316, will, therefore, indicate whether the core is in a central position, at which time no signal will be applied to the amplifier, or above or below this central position and by how much by its phase and amplitude, and consequently, will indicate whether the half-width of the blade strip 10 is on target or whether it is smaller or larger than the desired standard and by how much.

The differential transformer 320 is provided to compensate for drifts in the differential transformer 202 and wear of the carbide key 194, and to permit changes to be conveniently made in the half-width standard desired. The differential transformer 320 is preferably exactly like the transformer 202 and is connected in the same manner to the input of the amplifier 316. The core 322 of the transformer 320 can be manually adjusted up or down by means of the adjusting knob 328 and since the primary winding 330 is energized from the same source of 5000 cycle alternating current as the primary winding of the transformer 202, the transformer may be set to augment either phase and to detract from the other. Since the signal introduced into the amplifier 316 is the algebraic sum of the outputs of the transformers 320 and 202, adjusting the core of the transformer 320 has the effect of electrically moving the effective null of the transformer 202. In this way the said null, and thus the set-point of the control system, can be conveniently adjusted. If it is found that no compensation in either phase is needed, the core of the transformer 320 is merely adjusted to its central or neutral position.

The a.c. error signal from the differential transformer 202 is modified by the compensating transformer 320 is amplified by the amplifier 316 and the resulting amplified error signal which is of the same phase as that applied to the input of the amplifier is passed through the band-pass filter network 336 to 339. The pure 5000 cycle error signal is now further amplified by the amplifier 334 and the amplified error signal is applied across the primary winding 344 of the transformer 345 to induce voltages in the secondary windings 348 and 349 which are applied to the plates of the associated tubes 360 and 364. Because of the opposite phasing of the secondary windings 348 and 349, the a.c. voltages applied to the plates of the tubes 360 and 364 will be of opposite phase, one being of the same phase as the voltage applied to the grid thereof and the other being of the opposite phase. The tube in which the voltages applied to the grid and plate are in phase will conduct during the positive halves of the cycles by an amount substantially proportional to the amplitude, while no conduction will take place in the other tube. The capacitor 362 or 367 connected to the secondary winding 349 or 348 associated with the conducting tube will acquire a charge substantially proportional to the average amplitude of the voltages induced in such winding while the other capacitor will acquire no charge.

Some phase shift of the 5000 cycle error signal occurs in the differential transformers 202 and 320 and in the subsequent circuitry including the primary winding 344 of the transformer 345, and the phase shift network 356 is provided in order to phase the a.c. voltages applied to the grids of the tubes 351 and 352 exactly with the voltages induced in the secondary windings 348 and 349 of the transformer by the error signal appearing across the primary winding 344. This network comprises two branches connected in parallel across the output of the 5000 cycle source 332, one branch consisting of a resistor 378 and a capacitor 379 connected in series and the other branch consisting of a capacitor 380 and a resistor 381 connected in series. A potentiometer 382 is connected between the juncture between the resistor 378 and the capacitor 379 and the juncture between the capacitor 380 and the resistor 381, the slider 384 of the potentiometer being connected to the grids of the amplifier tubes 351 and 352 through the resistors 353 and

354, respectively. By varying the positions of the potentiometer slider 384 the phase of the a.c. current applied to the tubes 351 and 352 may be shifted one way or the other with respect to the a.c. error signal that appears across the primary windings 344. Thus proper in-phase and anti-phase relations may be obtained.

PROGRAMMER

The programmer shown in Fig. 14 accepts the error signals derived from the comparison between the upper two bevels and the error signal indicating the deviation of the upper half-width of the blade strip from the preset standard, determines the correction required in the positions of the two grinding heads operating upon the two upper bevels, and then establishes circuit connections to further circuits to effect actuation of the adjusting means of these heads to move them inwardly or outwardly by the number of steps required to correct the errors in the blade geometry as indicated by the bevel balance and half-width error signals. The programmer then, by operating appropriate switches, accepts the error signals derived from the comparison between the two lower bevels and the error signal derived from the comparison of the lower half-width with the preset standard, determines the amount of correction required in the positions of the two grinding heads that operate upon the two lower bevels to correct for the error indicated by the error signals to bring the bevels into balance and to bring the half-width to the preset standard and effects the required adjustments of these heads. The resulting corrections in the positions of the grinding heads are such that each grinding head will be moved only in one direction by the required amount determined by the programmer to correct for the bevel imbalance and/or the half-width deviation in a coordinated manner. Thus if the bevel error signals indicate that the grinding head operating on bevel 1 of the blade strip should be moved inwardly two steps in order to correct for the bevel imbalance while the half-width detector indicates that no correction of the blade half-width is necessary, the programmer will cause the grinding head operating on bevel 1 to move inwardly one step and the grinding head operating on bevel 3 to move outwardly one step to effect the necessary two step correction in the bevel without thereby affecting the half-width. If the bevel error signals indicate that the grinding head operating on the bevel 1 should be moved inwardly one step, and the error signal from the half-width detector indicates that the half-width is too large and should be reduced by an amount corresponding to one inward step of each of the grinding heads, the programmer will cause the grinding head operating upon the bevel 1 to move inwardly two steps and the grinding head operating on bevel 2 to move inwardly one step to affect the correction required both in the bevel balance and in the blade half-width in one correction sequence, without reversals.

It will be apparent from considering the grinding head correction chart of Fig. 17 that when there is a residual half-width error after the correction has been effected, which error is smaller than one requiring a full correction step of the grinding heads, the correction is made so that the resulting half-width will be on the smaller rather than the larger side of the target size since wear of the grinding wheels will tend to increase the half-width and thus bring it toward the target size. This will result in a smaller number of corrections for a given half-width error. Moreover, the half-widths obtained will, under these circumstances, tend to "bracket" the desired size.

The programmer comprises generally the two meter relays 21 and 30 deflected respectively in accordance with the bevel error signals and the error signals from the half-width detector, a system of relays, and a multi-bank stepping switch wherein the contacts are so connected to the relays and to each other as to produce in appropriate circuits a number of output pulses corresponding to the number of steps required by a pair of grinding heads to substantially correct for the errors reflected in the two meter relays.

Input terminals 400 to 407 are connected to the output terminals of the d.c. amplifiers 19, 20, 28, 44, 46 and 48 (Fig. 1) and these terminals are connected to respective contacts of a stepping type cam switch 408 which may be of a type manufactured and sold by the Automatic Electric Company, Northlake, Illinois, under the designation "OCS". Such a switch comprises generally a rotating cam 409 that has equal portions along its periphery alternately depressed and raised so as to alternately raise and lower a cam follower 410 as the cam is rotated step-by-step by an actuating mechanism in response to electric pulses. The cam actuating mechanism is illustrated as a ratchet mechanism comprising a ratchet wheel 411, a reciprocating pawl 412 and a solenoid 413 connected to the ratchet pawl, the arrangement being such that cam 408 is advanced from a depressed position to a raised position in response to a signal pulse applied to the winding of the solenoid 413 and is advanced to a depressed position

by a second pulse, etc. The cam follower 410 is connected to a plurality of movable contact bars each cooperating with two pairs of fixed contacts 415 to 420, the contact pairs 420 being located at the upper right hand side of the drawing. The input terminals 400 and 401 which are connected to the outputs of the d.c. amplifiers 44 and 46 (Fig. 1) of the bevel comparator for the lower bevels 2 and 4 of the blade strip are connected to the upper contacts of the contact pairs 418 and 419 and the terminals 402 and 403 which are connected to the outputs of the d.c. amplifiers 19 and 20 of the bevel comparator for the upper bevels 1 and 3 of the blade strip are connected to the lower contacts of the contact pairs 418 and 419. The terminals 404 and 405 which are connected to the d.c. amplifier 48 of the lower half-width detector are connected to the upper contacts of the contact pairs 416 and 417 and the corresponding terminals 406 and 407 connected to the d.c. amplifier 28 of the top half-width detector are connected to the lower contacts of the contact pairs 416 and 417. It will thus be seen that when the cam follower 410 is in its depressed position wherein the movable contact bars engage the associated lower pairs of contacts, the upper bevel balance error signals and the upper half-width error signals will be connected to the respective meter relays 21 and 30, and when the cam follower 410 is in its elevated position, the lower bevel balance error signals and the lower half-width error signals will be connected to the respective meter relays 21 and 30. The upper and lower output contacts of each of the contact pairs 416 to 419, inclusive, are connected together. The output leads from contact pairs 418 and 419 are connected to the opposite ends of the deflection coil 422 of the meter relay 21 and the output leads from the contact pairs 417 and 416 are connected to the opposite ends of the deflection coil 423 of the meter relay 30. Thus, in the position shown of the stepping switch 408, the signals derived from the upper bevels 1 and 3 will be applied to the opposite ends of the deflection coil 422 of the bevel balance meter relay 21 and the error signals from the upper half-width detector will be applied to the deflection coil 423 of the half-width meter relay 30. When the cam follower 410 is in its elevated position, the signals derived from the lower bevels 2 and 4 will be applied to the deflection coil 422 of the bevel balance meter relay 21 and the error signals from the lower half-width detector will be applied to the detection coil 423 of the half-width meter relay 30. As will hereinafter be described, the contact pairs 420 prepare the output circuit for correction of the two bottom grinding heads when the associated contact bar is in its upper position.

The pointer 424 of the meter relay 21 is adapted to sweep freely above a plurality of contacts indicated as O, plus 1, plus 2, plus 3 and minus 1, minus 2, minus 3 and the corresponding pointer 425 of the meter relay 30 is adapted to sweep freely above a plurality of contacts marked plus 0, plus 1, plus 2, plus 3 and minus 0, minus 1, minus 2, minus 3. The pointers 424 and 425 normally do not engage or make electrical contact with the contacts associated therewith but are adapted to be clamped into engagement therewith upon actuation of a pair of clamping coils 426 and 427, respectively. The meter relays may be of the general construction illustrated in Fig. 15 in which there is provided a swingable armature 429 adapted to clamp the contact arm 424 against the underlying contacts when the coil 426 is actuated, and may, for example, be of a type manufactured and sold under the trade name "LIAD" by the Assembly Products Co., Chesterland, Ohio.

The contacts of the meter relays 21 and 30 are connected to adjacent respective wipers of a multibank stepping switch 430 so that the minus 3 contact of the meter relay 21 is connected to the wiper of bank S and the plus 3 contact of the meter relay 30 is connected to the wiper of bank B and the intermediate contacts are connected to individual wipers of respective intermediate banks R to C as indicated.

The contacts 431 of the stepping switch 430 are arranged in 26 levels and the contacts in the banks B to S are connected in four distinct groups connected, respectively, to the output leads 432, 433, 434 and 435. The group of contacts 431 connected to the output lead 432 cooperate with the group of contacts connected to the output lead 434 to produce, when traversed by the wipers associated therewith when an appropriate error condition exists, correction signals to move the grinding heads outwardly, and the groups of contacts connected to the output leads 433 and 435 will, when traversed by the associated wipers when an appropriate error condition exists, produce correction signals to move the grinding heads inwardly. In other words, a corrective outward step of any grinding head will take place only when signals from the groups of contacts associated with the output leads 432 and 434 coincide and a corrective inward step of any grinding head will take place only when signals derived from the groups of contacts associated with the output leads 433 and 435 coincide as will hereinafter be described.

The output lead 432 is connected through

normally closed contacts 436 of a relay R3 and the energizing winding of a relay R4 to a ground bus 437. The output lead 433 is connected through the energizing winding of the relay R3 to the ground bus 437 and, similarly, the output lead 435 is connected to the ground bus through the energizing winding of a relay R1. The output lead 434 is connected to the ground bus 437 through normally closed contacts 438 of the relay R1 and the energizing winding of a relay R2. Each of the windings of the relays R1 through R4 is shunted by a conventional spark-suppressing circuit such as a resistor and a capacitor connected in series.

The stepping switch 430 is actuated by a solenoid 440 through a ratchet mechanism which may be similar to that illustrated in connection with the cam switch 408 and arranged so as to advance the stepping switch 430 by one step when the solenoid 440 is released after having been energized. The energizing winding of the solenoid 440 is connected to the d.c. line 450 through the normally closed contacts 442 of the timing relay R7. The contacts 442 of the relay R7 are shunted by a homing circuit comprising disconnect contacts of the stepping switch 430 and normally closed contacts 446, 447 and 448 connected in series. Relay R7 also controls the energization of the wiper of bank A of the stepping switch through its contacts 449. The energizing winding of the relay R7 is connected to the d.c. line 450 through contacts 451 operated by a timing cam 452 continuously rotated by a timing motor 454 as long as the circuit is energized. The timing cam 452 is so shaped that it will maintain the contacts 451 closed through approximately 80 per cent of its revolutions and open during the remaining 20 per cent. The contacts 451 are shunted by homing contacts 443 of a relay R6 and contacts 445 of a relay R5 connected in series.

The timing motor 454 which is shown in phantom in juxtaposition to the cam 452 and in full lines in the upper right of Fig. 14 is connected in parallel with the energizing windings of the relay R6, which windings are connected to an a.c. source 457 through a normally open push-button start switch 456 and a normally closed stop switch 459. When the relay R6 is energized by momentary operation of the start switch 456, the relay will remain energized through its hold contacts 458 connected in a circuit that bypasses the start switch 456. The d.c. line 450 may conveniently be energized from a full wave rectifier 460 connected across the secondary winding of a power transformer 462.

The operated relay R6 closes its normally open contacts 468 to furnish d.c. power to the clamping coils 426 and 427, the pointers 424 and 425 of the meter relays 21 and 30, respectively, and the contact wiper of the A bank of the stepping switch 430. The clamping coils 426 and 427 are operated by a relay R8 whose normally open contacts 479 connect one side of the parallel connected clamping coils to ground, the other side of the parallel connected clamping coils being connected to the d.c. line through the contacts 468 of the relay R6.

The operating solenoid 413 for the switch 408 is connected through the upper contacts of the contact pair 415 to the 24th level contact of the A bank of the stepping switch 430. Normally open contacts 470 of the relay R5 connect the 24th level contact of the A bank to the solenoid 413. The energizing winding of the relay R5 is connected to the 25th level contact of the A bank through normally open contacts 472 of the relay R6. Relay R5, when operated, closes hold contacts 473 and establishes a holding circuit to the d.c. line through the contacts 468 of relay R6.

In order to permit a grinding head to complete the correction called for by a signal derived from a particular contact level in the stepping switch 430 before the next correction signal is directed thereto, the contacts of the stepping switch are so arranged that signals are alternately applied to the grinding heads on opposite sides of the blade strip whereby each grinding head is given a time interval corresponding to two steps of the stepping switch to complete the correction called for. To this end, there is provided a relay R9 whose energizing winding is connected between the ground bus 437 and the contacts in levels 9, 11, 13, 15, 17, 19 and 21 of the A bank of the stepping switch 430 for switching the output signals from one head to the other as will hereinafter be described.

The pointers 424 and 425 of the meter relays 21 and 30 are connected to the d.c. line through contacts 474 operated by a cam 476 and the contacts 468 of the relay R6. The timing of the contacts 451 and 474 associated with the respective cams 452 and 476 driven from the motor 454 is shown in Fig. 16. It will be seen from Fig. 16, that the contacts 451 will be closed during the first 80 per cent of the cycle and open during the remaining 20 per cent and that the contacts 474 will be open during the first 25 per cent of the cycle, closed for the next 20 per cent, and open for the remainder of the cycle. The significance of this timing arrangement will appear from the description of the operation of the circuit associated therewith.

The stepping switch 430 is provided with a homing circuit which connects the ener-

gizing windings of the solenoid 440 to the d.c. line through the disconnect contact 444, the contacts 446 of the relay R6, the contacts 447 of the relays R5 and the interrupter contacts 448 operated by the solenoid 440. The interrupter contacts 448 close when the solenoid 440 is deenergized and open when the solenoid is energized and thus serve to operate the solenoid until the circuit is interrupted by the disconnect contacts 444 when the stepping switch reaches its starting or home position.

The relay R8 which is provided for controlling the operation of the clamping coils 426 and 427 of the meter relays 20 and 31, respectively, is provided with a hold circuit that includes disconnect contacts 476 which are opened by the stepping switch 430 when the latter reaches home position and the hold contacts 478 of the relay R8. The relay R8 is energized from the 8th level contact of the A bank of the stepping switch 430 and when the latter reaches its 8th level position, the wiper of the A bank completes the energizing circuit for the relay to close the hold contacts 478. The relay R8 when thus energized closes contacts 479 to energize the clamping coils 426 and 427 until the disconnect contacts 476 interrupt the hold circuit of the relay when the stepping switch reaches its home position.

The signals generated by the contact bank of the stepping switch 430 in accordance with the positions of the pointers 424 and 425 of the meter relays 21 and 30 are converted into appropriate grinding head correction signals by a circuit generally indicated at 480. The relays R1 to R4 establish the correction signal circuits and a relay R9 determines whether the circuits thus established will control either the grinding heads 1 and 2 or the grinding heads 3 and 4. A pair of output terminals 481 and 482 control the operation of grinding head 1, and the pairs of terminals 483, 484; 485, 486; and 487 and 488 control respectively, the operation of the grinding heads 2, 3, and 4. A signal on the left-hand terminal of each pair of terminals, i.e. the even numbered terminals, will result in an inward movement of the associated grinding head and will be termed "in" terminals. Correspondingly, a signal on one of the right-hand or odd numbered terminals will result in a rearward movement of the associated grinding head and will be termed an "out" terminal. It will be noted from the circuit 480 that the "in" terminals 482, 484, 486 and 488 will be connected to the line 489 through the contacts 420 only when both relays R1 and R3 are simultaneously operated to close their respective contacts 490, 491 and 492, 493 and the "out" terminals 481, 483, 485, and 487 can be connected to the line 489 only when relays R2 and R4 are simultaneously operated to close their respective contacts 494, 495 and 496, 497. The relay R9 when deenergised will maintain the terminals 483, 484, 487, and 488 associated with the grinding heads 3 and 4 situated on one side of the razor blade strip, connected to the contact bank 490 to 497 through its back contacts and when energized from the stepping switch 430 will maintain the terminals 481, 482, 485 and 486, associated with the grinding heads 1 and 3 situated on the other side of the blade strip, connected to the contact bank through its front contacts. The terms "front" and "back" contacts are used herein to designate the fixed contacts that are engaged by the movable contact arm when the associated relay is energized and deenergized respectively.

It will be appreciated from the above description that the correction signal conditions for the grinding heads are set up in the circuit 480 by the relays R1 to R4 and that the appropriate grinding head is selected jointly by the rotary switch 408 through its contact pair 420, which selects either the top or the bottom grinding heads and by the relay R9 which selects the grinding heads on one side of the strip or the other.

The line 489 is connected to a power terminal 498 through the front contact 500*b* of the relay R5. The back contact 500*a* of the relay R5 connect the power terminal to a circuit for manually actuating the grinding heads through a switch 502. The grinding heads cannot therefore be manually actuated while under the control of the selection circuit 480.

OPERATION OF THE PROGRAMMER

The programmer illustrated in Fig. 14 is placed in operation by momentarily closing the push-button switch 456 to energize the relay R6, by connecting its energising winding to the a.c. source 457 whereupon the relay will lock itself in through its hold contacts 458 which shunt the push-button switch 456 and which will retain the relay R6 operated until the hold circuit is broken by the operation of the stop switch 459. The energization of the relay R6 will open the contacts 446 to interrupt the homing circuit of the stepping switch 430, close the contacts 468 to connect the d.c. line 450 to the pointers 424 and 425 of the meter relays 21 and 30, to the clamping coils 426 and 427 through the cam operated contacts 476, to the wiper of bank A of the stepping switch 430 through the contacts 449 of the relay R7, and to the hold circuit of the relay R5, and close the contacts 472 in the energizing circuit of

the relay R5. The a.c. source 457 is energized from the same source of power as the grinding machine. The programmer cannot, therefore, be placed in operation unless the grinding machine is energized and until the latter has been in operation for a period of time determined by the delay device.

The motor 454 which is connected in parallel with the relay R6 will now drive the switch operating cams 452 and 476 in a clockwise direction as indicated in the drawing. The cam 452 will open and close the contacts 451 that control the energization of the relay R7 which through its contacts 442 will in turn energize and deenergize the operating solenoid 440 of the stepping switch 430. Thus the solenoid 440 will be energized when the contacts 451 are open and deenergized when these contacts are closed. The cam 452 closes the contacts 451 during the major portion of the cycle which may be 80 per cent of its revolution and opens the contacts during the last 20 per cent of the cycle as indicated in the timing diagram of Fig. 16. Energization of the solenoid 440 prepares the advancing mechanism of the stepping switch 430 to move the switch one step, such movement taking place when the solenoid is again deenergized.

When the stepping switch 430 moves the wipers from level 1 to level 2 contacts 444 will close and prepare the homing circuit that includes the contacts 446, 447 and 448 for returning the stepping switch to its home position if the programmer should be turned off before the switch has completed its cycle. The stepping switch 430 will thereafter be stepped from level to level by successive energization and deenergization of the solenoid 440 for each revolution of the timing cam 452. When the stepping switch 430 moves away from its starting position, the contacts 476 will close to prepare the holding circuit for the relay R8, which, however, will remain deenergized since its hold contacts 478 are open.

When the stepping switch 430 reaches the 8th level, the wiper of the A bank will connect the energizing winding of relay R8 to the d.c. line 450 through the contacts 449 of the energized relay R7 to energize the relay R8 and close the hold contacts 478 which will complete the holding circuit for the relay through the closed contacts 476. The closed contacts 479 of the relay R8 will complete the energizing circuit for the clamping coils 426 and 427 of the meter relay 21 and 30 to clamp the contact arms 424 and 425 against the underlying contacts for the remainder of the cycle of the switch 430. It should be noted, however, that the relay R5 is still deenergized and its front contacts 500*b* are open so that no correction signals will appear on the output terminals of the circuit 480. The relay R5 is energized when the stepping switch reaches the 25th level at which point the wiper arm of the A bank connects the energizing winding of this relay to the d.c. line 450 through the contacts 449 of the relay R7 and the closed contacts 472 of the relay R6. The relay R5 will now remain energized through its hold contacts 473 as long as the relay R6 remains energized.

In order to stabilize and settle the system including the meters and integrating circuits after the programmer is initially turned on and in order to condition the circuit to apply correction signals first to the top grinding heads, the stepping switch is permitted to sweep through one cycle before the output circuit is energized. This initial sweep of the stepping switch 430 will advance the cam switch 408 to the position shown, if it is not already in that position, in which position it applies correction signals to the grinding heads 1 and 3. This is accomplished by a connection between the 24th level contact of the A bank and the operating solenoid 413 of the cam switch 408 through the upper contacts of the contact pairs 415 thereof. Thus, when the wiper of the A bank reaches the contact in the 24th level, the solenoid 413 will be energized if the stepping relay 408 is initially in a position wherein the follower 410 is elevated, to move the stepping relay to the desired starting position as shown in the drawing. If the cam switch 408 is already in this position, the upper contacts of contact pairs 415 will be open and the switch will remain in this position. It will be seen that after the stepping switch 430 has made its initial cycle, the stepping switch 408 will be in the required position to connect the signals derived from the scanning of the upper bevels 1 and 3 of the blade strip and from the upper half-width detector 23 to the respective meter relays 21 and 30, the relay R5 will be energized to connect power to the selector circuit 480, and the movable pointers 424 and 425 of the meter relays 21 and 30, respectively, will be deflected in accordance with the signals applied to the deflection coils 422 and 423 since the holding circuit for the relay R8 was interrupted when the contacts 476 were opened and when the stepping switch 430 reached its home position, thus releasing the contact arms 424 and 425 for movement in accordance with signals applied to their respective deflection coils. The continuously running motor 454 will rotate the cam 452 to alternately energize and deenergize the solenoid 444 to advance the stepping

switch 430 step by step, and the cam 476 to momentarily energize the meter pointers 424 and 425 while the stepping switch is at rest between successive steps.

The meter pointers are free to seek their steady position in accordance with the d.c. error signals applied to their respective deflection coils while the stepping switch moves from its starting position to the 8th level at which time the relay R8 is again energized to clamp the meter pointers 424 and 425 of the meter relays 21 and 30 against the underlying contacts.

In the automatic grinding systems described herein, the grinding heads are arranged to be moved inwardly or outwardly by about one ten-thousandth of an inch in response to a single correction signal applied to one of the output terminals 481 to 488 from the selector circuit 480. The number of corrective steps required to be taken by a grinding head will, of course, depend upon how much the blade geometry of the part of the blade strip sampled departs from the desired geometry as reflected in the magnitude of the error signals. The various circuits are designed and calibrated so as to produce error signals to effect grinding head corrections in accordance with the tabulation of Fig. 17. Signals on the terminals 481 to 488 will control movements of the grinding heads in accordance with the following table:

Terminal No.	*Grinding Head*	*Direction of Movement*
481	#1	Outwardly
482	#1	Inwardly
483	#3	Outwardly
484	#3	Inwardly
485	#2	Outwardly
486	#2	Inwardly
487	#4	Outwardly
488	#4	Inwardly

It will be noted from the correction chart of Fig. 17 that if the half-width error signal deflects the meter relay 30 to either its "plus zero" or "minus zero" contact and if the bevel balance deviation is zero as indicated by zero deflection of the meter relay 21, no correction will be required by the grinding heads associated with the bevels being sampled. If bevel 1 is smaller than bevel 3 by such an amount that the resulting error signal deflects the meter relay 21 to its plus 1 contact and if the upper half-width of the blade strip is too large by an amount that will deflect the meter relay 30 to its plus 1 contact, these errors in the geometry of the upper half of the blade strip will be corrected by moving grinding head 1 inwardly two steps and the head 3 inwardly one step.

In order to explain the operation of the circuit of the stepping switch 430, Fig. 14, it will first be assumed that the pointer 424 of the meter relay 21 is deflected to its plus 1 contact and clamped in that position by the clamping coil 426, that the pointer 425 of the meter relay 30 is deflected to its plus 1 contact and held there by the clamping coil 427 and that the stepping relay 408 is in the depressed position shown to sample the error signals from the upper half of the blade strip. It will be recalled that an output signal will appear on one of the output terminals 481 to 488 only when a signal appears simultaneously on the pair of leads 432, 434 or on the pair of leads 433, 435. Under the assumed conditions, coincidence of signals on the output leads 433 and 435 or on the output leads 432 and 434 will first take place when the stepping switch 430 reaches the 15th level at which time the wiper of the bank N engages a contact connected to the lead 433, the wiper of the bank D engages a contact connected to the lead 435 and the wiper of bank A engages a contact connected to the relay R9 to energize this relay. The relays R1 and R3 will be energized when the cam 476 closes the contacts 474, to close the contacts 490, 491, 492, and 493. This will connect output terminal 482 to the power terminal 498 through the closed front contacts of the relay R9 associated therewith, the closed contacts 491 and 493, the closed lower contacts of contact pairs 420, the closed front contact 500*b* of the energized relay R5. The potential appearing on the output terminal 482 will, through further circuitry to be described, cause grinding head 1 to move one step inwardly.

Coincidence of signals on the output leads 433 and 435 will next take place when the stepping switch 430 reaches the 17th level and relays R1, R3 and R9 are energized as explained above to again apply signal potential to the output terminal 482 to cause grinding head 1 to move another step inwardly. The grinding head 1 will now have been moved inwardly two steps as required by the correction chart of Fig. 17. It will be noted that a delay corresponding to one contact space is provided between the two output signals so that sufficient time is provided to allow the grinding head to complete the corrective step before the next corrective signal is applied thereto. When the stepping switch 430 reaches the 18th level, the leads 433 and 435 will again be energized to energize the relays R3 and R1. Since the relay R9 remains deenergized in the even numbered levels the signal potential will now be applied to the output terminal 484 to cause grinding head 3 to be moved inwardly one step.

It will be appreciated from the above example that if the pointers of the meter relays 21 and 30 are both deflected to their plus 1 contacts when the clamping coils 426 and 427 are operated at the 8th level, the contacts in levels 15, 17 and 18 of the corresponding banks will be connected to the respective output leads 433 and 435 to cause two spaced signals to appear on the output terminal 482 and one signal to appear on the output terminal 484 thereby causing the grinding head 1 to move in two steps and the grinding head 3 to move in one step as required by the chart of Fig. 16.

Assume now that the half-width error signal derived from the upper half of the blade strip deflects the associated meter relay 30 to its "Minus zero" position and that the error signal from the comparison of bevels 1 and 3 of the blade strip deflects the meter relay 21 to its plus 3 position which indicates that the bevel 1 is much narrower than the bevel 3 with which it is compared. Referring again to the chart of Fig. 17, it will be seen that this condition will be corrected by moving grinding head 1 inwardly one step and the grinding head 3 outwardly two steps.

The first signal coincidence on the leads 433 and 435 or 432 and 434 will occur when the stepping switch reaches its 13th level wherein the wipers of banks F and K will operate both relays R3 and R1 through the leads 433 and 435 and apply a signal potential to the output terminal 482 through the closed contacts 493 and 491 and the associated front contacts of the energized relay R9. This will cause the grinding head 1 to be moved inwardly one step. When the stepping switch 430 reaches the 16th level, contacts respectively connected to the leads 432 and 434 will be engaged by the wipers of the banks F and K to energize the relays R4 and R2 to close the contacts 494, 495, 496 and 497. The relay R9 will be deenergized since the stepping switch is in an even numbered level. It will be seen that this will place an output signal on the terminal 483 to move the grinding head 3 outwardly one step. The same signal conditions will occur at the 18th level at which time another signal will appear on the output terminal 483 to cause the grinding head 3 to move outwardly another step. It will thus be seen that as the stepping switch 430 is moved through one cycle, the output terminal 483 will be energized twice to cause the grinding head 3 to move outwardly two steps and the output terminal 482 will be energized once to move the grinding head 1 inwardly one step in accordance with the chart shown in Fig. 17 to correct for the dimensional deviations of the upper half of the blade strip from the desired standard as detected by the half-width detector and the bevel comparator.

When the stepping switch 430 reaches the 24th level it will energize the solenoid 413 of the cam switch 408 through the closed contracts 470 of the energized relay R5 to cause the cam switch to advance one step to move all the contact arms operated by the cam follower 410 against the associated upper contacts and disconnect them from the lower contacts and, hence, apply the signals derived from the bevel scanners and the half-width deviation detector of the lower half of the blade strip to the meter relays 21 and 30 and to prepare the switching circuit 480 for connecting signal power to the output terminals 485 to 488 associated with the grinding heads 2 and 4.

When the stepping switch 430 is now caused to go through another cycle of operation, it will direct the corrective output signals to the output terminals 485 to 488 to effect the required corrections of the grinding heads 2 and 4 operating on bevels 2 and 4 of the lower edge of the blade strip. These grinding heads will also be corrected in accordance with the chart of Fig. 17 substituting therein grinding head 2 for grinding head 1 and grinding head 4 for grinding head 3.

If the system should be shut off while the stepping switch 430 is in mid-cycle, relays R6 and R5 will become deenergized to close the contacts 443 and 445 to energize the relay R7 and open the contacts 442, and to close the contacts 446 and 447 to complete the homing circuit for the solenoid 440 through the closed disconnect contacts 444 of the stepping switch 430 to place the homing circuit under the control of the interrupter contacts 448 associated with the solenoid 440. The interrupter contacts 448 which open when the solenoid 440 is energized and close when the solenoid is deenergized and will cause the solenoid to advance the stepping switch 430 rapidly until it reaches home position and interrupts the homing circuit by opening the contacts 444.

GRINDING HEAD CONTROL CIRCUIT

Fig. 18 shows the circuits for generating the necessary pulse trains for operating the stepping motors identified herein that move the selected grinding heads inwardly or outwardly in response to the correction signals derived from the programmer shown in Fig. 14. The terminals 481 to 488 of the programmer are connected to the correspondingly numbered terminals of the circuit shown in the Fig. 18. It was noted in connection with the description of the operation of the programmer that separate output terminals are provided for moving each grinding head inwardly and outwardly. Each pair of terminals, 481-482, 483-484, 485-486 and 487-488 (Fig. 18) associated with one of the four grinding heads is connected to a

switching unit 510 to 513 that controls a pulse train generating circuit and applies pulse trains to the motor of the associated grinding head in accordance with correction signals applied to such terminals. Thus, the input terminals 487 and 488 associated with the grinding head 4 are connected to the switching unit 510, and the terminals 483 and 484 associated with the grinding head 3 are connected to the switching unit 511. The terminals 485 and 486 associated with the grinding head 2 are connected to the switching unit 512, and the terminals 481 and 482 associated with the grinding head 1 are connected to the switching unit 513. Since the switching units 510 to 513 are identical, only the switching unit 510 will be described in detail.

The switching unit 510 comprises relays 515, 516 and 517, which are operated in accordance with correction signals appearing on terminals 487 and 488. The input terminal 488 is connected to the operating winding of the relay 515, and the input terminal 487 is connected to the operating winding of the relay 517. The windings of the relays 515 and 517 are connected to a ground bus 520 through the back contacts 522 of a relay 523 of the switching unit 511 that corresponds to the relay 516 of the switching unit 510. Similarly, the operating windings of the relays 524 and 525 of the switching unit 511 are connected to the common ground bus 520 through back contacts 526 of the relay 516. It will thus be seen that when the relay 516 is energized, the relays 524 and 525 of the switching unit 511 will be disconnected from ground and, correspondingly, when the relay 523 is energized, the relays 515 and 517 of the switching unit 510 will be disconnected from ground. This arrangement assures that only one of the switching units 510 and 511 can be connected to the drive motor of its associated grinding head at any one time.

The hold circuit for each of the relays 515 and 517 is routed through contacts of the other relay so as to preclude simultaneous energizations of these relays as a further guard against misoperation of the system. The hold circuit for the relay 515 can be traced through its hold contacts 528 and the back contacts 529 of the relay 517 to a power line 532. Similarly the hold circuit for the relay 517 can be traced through its hold contacts 534 and the back contacts 530 of the relay 515 to the power line 532. The operating winding of the relay 516 will be connected to the power line 532 when either one of the relays 515 or 517 is energized to close front contacts 530 or 529.

The grinding heads are provided with respective stepping motors 536 to 539 each adapted to move the associated grinding head step by step inwardly or outwardly as required, by equal increments. The stepping motors may conveniently be synchronous permanent magnet type motors used as d.c. stepping motors and may be of a type manufactured and sold by The Superior Electric Company, Bristol, Connecticut, under the trademark Slo-Syn. When a d.c. voltage is applied to the two phases of the field windings the motor will lock into a magnetic hold position. If the d.c. voltages applied to the respective phases are then sequentially reversed, the motor will advance, say 1.8 degrees or one two-hundreth of a revolution, in one direction or the other, depending on the sequence followed for each reversal in both phases. Thus, designating the two phases as phase A and phase B, the motor will be stepped in one direction by applying a sequence of d.c. pulses 540, Fig. 19 to phase A and a sequence of d.c. pulses 541 to phase B, and in the other direction by applying the pulse sequence 540 to phase B and the pulse sequence 541 to phase A. It will be noted that the motor in its initial starting position will have positive d.c. voltages applied to both phases. If now the voltages aplied to the two phases are succesively reversed so that phase A is first reversed, then phase B is reversed, then phase A is restored to a positive potential, and thereafter phase B is restored to a positive potential, the motor will have advanced by two increments in one direction which we herein will assume to be in a direction such as to displace the associated grinding head inwardly or toward the blade strip. If now the sequence of the reversals in the potentials applied to phases A and B is reversed so that the potential on phase B is reversed before the potential on phase A, i.e. the pulse sequence 540 is applied to phase B and the pulse sequence 541 is applied to phase A, the motor will advance in the opposite direction or in a direction that will move the associated grinding head outwardly. The gearing that connects the stepping motors 536 to 539 to their respective grinding heads is selected so that it may take, for example, 16 reversals of each phase to move the grinding head associated therewith one ten-thousandth of an inch inwardly or outwardly as the case may be, which movement is referred to herein as one step of the grinding heads.

It will be clear to those skilled in the art that the alternate series of pulses illustrated in Fig. 19 may be generated in various ways such as by single pole or double pole switches, cams, relays or through the use of commutator brush arrangements, or electronically by using transistors, tubes or equivalent devices. In the embodiment illustrated herein, each train of positive and negative d.c. pulses is produced during one revolution of a rotating cam arranged to operate a movable contact arm engageable with either

of a pair of stationary contacts. A single pulse generating equipment 542 is provided to generate the two pulse trains 540 and 541 for driving the motors 537 and 536 associated with the grinding heads 3 and 4, respectively, and a separate identical pulse generating equipment 543 is provided to generate the two pulse trains 540 and 541 for driving the motors 539 and 538 associated with the grinding heads 1 and 2, respectively. Pulse generating equipment 542 comprises driving means which for the sake of illustration is shown as a motor 545 that drives a plurality of cams 546 to 549 and 579. Each of the cams 547 and 548 is provided with 16 alternately raised and recessed surface portions and operate respective contact arms 550 and 551 through suitable cam followers to cause each of the arms to engage alternately a pair of contacts connected, respectively, to a positive and a negative d.c. potential. The cams 547 and 548 are so formed as to cause the respective contact arms 550 and 551 to become energized corresponding to the pulse trains 540 and 541 during each revolution. The cam 546 is provided for the purpose of deenergizing the motor 545 after the cam shaft has completed one revolution as will presently be described, and the cam 549 serves to stop the cam shaft exactly in the desired initial position wherein the cam followers of cams 547 and 548 are both in elevated position with the contact arms 550 and 551 associated therewith in engagement with the positive contacts to assure that the stepping motor will receive the full sequence of pulses when the pulse generating circuit is initially energized. The cam 549 is provided with a notch 552 in which a locking detent 553 is received when the cam shaft reaches its initial or home position. A solenoid 554 is provided to retract the detent 553 from the notch 552 when the motor 545 is energized to permit the cam shaft to make one complete revolution before it is stopped by the detent dropping into the notch. A stepping switch manufactured by Automatic Electric Company, Northlake, Illinois, and sold under the designation "OCS" which is provided with cams that will operate switches as described and which includes means for automatically stopping it at the end of one complete revolution can suitably be used in place of the pulse generating equipment described for the purpose of illustration. A relay 556 is provided for starting the motor 545 and operates contacts 557 which, when closed, completes a circuit from the ground bus 520 to a negative d.c. line 558 through the energizing winding of the motor. The relay 556 also operates contacts 559 connected in the energizing circuit of the solenoids 554 to retract the detent 553 from the notch 552 in the cam 549 when the relay is energized. The pulse generating equipment 543 may be identical with the pulse generating equipment 542 and is connected between a positive d.c. line 560 and the ground bus 520..

The positive and negative potentials appearing on the d.c. lines 560 and 558 may be provided by a full wave rectifier circuit 561 comprising rectifiers 562, 562a, 563 and 563a connected in the usual manner to the secondary winding 564 of a transformer 565. The ground bus 520 which serves as the return path for the d.c. currents is connected to the midpoint of the secondary winding 564. The a.c. power lines 532 and 533 are connected to one side of the secondary winding 564 through contacts 566 and 567, respectively, operated by the respective cam 546 of the pulse generating equipment 542 and the corresponding cam 568 of the pulse generating equipment 543.

The relay 515 of the switching unit 510 also operates normally open contacts 570 and 571 which, when closed, respectively connect the movable contact arm 550 to phase A of the field windings of the stepping motor 536 and the movable contact arm 551 to phase B of this motor. Similarly, the relay 517 operates normally open contacts 572 and 573 which, when closed, respectively connect the movable contact arm 550 to phase B of the field windings of the motor 536 and the contact arm 551 to phase A. It will thus be appreciated that the contact arms 550 and 551 will be connected to phases A and B, respectively, when the relay 515 is energized and will be reversed when the relay 517 is energized.

The switching unit 511 which controls the operation of the stepping motor 537 includes reversing switches exactly like those of the switching unit 510 connected between the movable contact arms 550 and 551 and the field windings of the stepping motor 537.

The operation of the circuit shown in Fig. 18 will now be described assuming that the transformer 565 is energized to establish a positive potential on the line 560 and a negative potential on the line 558 with respect to the ground bus 520.

Assume now that a signal pulse appears on the terminal 488 from the correspondingly numbered terminal of the selector circuit 480 (Fig. 14) as a result of a determination by the programmer that the grinding head 4 should be moved one step inwardly. The signal pulse on terminal 488 will energize the relay 515 through a circuit that includes the closed contacts 522 of the relay 523 of the switching unit 511 to close the contacts 528, 530, 570 and 571 and energize the relay 516 through the closed contacts 528, the back contacts 529, and the front contacts 530. The energizing circuit for the normally energized relay 556 of the pulse generating equipment 542, which circuit in-

cludes the contacts 575 and 576 of the relays 516 and 523, respectively, will be interrupted when the relay 516 is energized and opens the contacts 575. Deenergization of the relay 556 will permit contacts 559 and 557 to close and thereby energize, respectively, the solenoid 554 to withdraw the detent 553 from the cam 549, to release the cam shaft, and the motor 545 to cause the latter to rotate the cams 546 to 549 and the cam 579. Rotation of the cam 546 will cause the contacts 566 to close and energize the line 532 that supplies power to the hold circuits of the relays of the switching units 510 and 511. The relays 515 and 516 will now be supplied with hold power from the line 532 through the front contacts 530 of the relay 515 after the signal pulse applied to the input terminal is terminated. The motor 545 will move each of the pulse train generating cams 547 and 548 through one revolution and cause the contact arms 550 and 551 operated thereby to alternately engage the positive and the negative contacts associated therewith so as to apply to the contact arms a series of alternate positive and negative potentials corresponding to the respective pulse trains 540 and 541 (Fig. 19). These trains of alternating positive and negative potentials are applied to the respective A and B phases of the motor 536 through the closed contacts 570 and 571 to rotate the motor in such a direction and to such an extent as to move the grinding head 4 inwardly by a distance referred to herein as one step (suitably one ten-thousandth of an inch). Both contact arms 550 and 551 will be positioned against the positive contacts after completion of the sixteenth step and remain there as the motor 545 is deenergized when the energizing circuit thereof is interrupted as a result of the opening of the contacts 566 by the cam 546, which in turn disconnects the hold line 532 from the source of power to deenergize the relays 515 and 516 to cause the contacts 575 to close and energize the motor controlling relay 556. The energized relay 556 will open the contacts 557 to deenergize the motor 545 and open the contacts 559 thereby deenergizing the solenoid 554 to permit the detent 553 to stop the cam 549 and the cam shaft in home position. The input signal applied to the terminal 488 is of sufficient duration to permit the motor 545 to advance the cam 546 and close the contacts 566 to energize the hold circuit for the relays in the switching units 510 and 511 before it is terminated, but short enough to terminate well before the cams 546 and 549 have made one complete revolution.

Assume next that an input signal appears on the input terminal 487 which, as previously explained, results from a determination by the programmer (Fig. 14) that the grinding head 4 should be moved outwardly one step. This signal will cause relay 517 and shortly thereafter relay 516 to operate, thus again disconnecting the switching circuit 511 from ground by opening the contacts 526 so as to prevent any accidental operation thereof while the switching circuit 510 is energized. Relay 516 will also open the contacts 575 to break the energizing circuit of the relay 556 to close the contacts 557 and 559 to cause the motor 545 to drive the pulse train generating cams 547 and 548 through another cycle of operation as described above. The d.c. pulses generated by the cams 547 and 548 will now be connected to the stepping motor 536 through the contacts 572 and 573 of the relay 517. The sequence of the d.c. pulses applied to the respective field windings of the d.c. stepping motor 536 will be the reverse of that described above resulting from an input signal on terminal 488 and the motor will now turn in the opposite direction and cause the grinding head 4 to move one step outwardly as required. The stepping motors 539, 538, and 537 will similarly be moved in one direction or the other in response to signals applied to the input terminals 481 to 486 to move the associated grinding heads 1, 2 and 3 correspondingly outwardly or inwardly.

The pulse train generating system 542 furnishes the operating pulses for the stepping motors 537 and 536 connected, respectively, to the grinding heads 3 and 4 that grind the bevels on one side of the blade strip and the pulse train generating system 543 furnishes the operating pulses for the stepping motors 539 and 538 connected respectively to the grinding heads 1 and 2 that grind the bevels of the other side of the blade strip.

Contacts 580 and 581 are provided in order to feed a smaller number of pulses than the full 16 pulses generated by the cams 547 and 548 to the stepping motor 536 if it is desired to reduce the distance the grinding head is moved in response to a signal pulse on the input terminals. Thus in order to reduce the grinding head step by a fourth, the cam 579 which is mounted on the same cam shaft as the cams 546 to 549 is designed so as to open the contacts 580 and 581 after each of the cams 547 and 548 has generated 12 pulses. A double pole, double throw control switch 584 is provided for selecting either the full 16-pulse trains or the shortened pulse trains. With the switch 584 in the position shown, full 16-pulse trains will be applied to the stepping motor 536 while in the other position the circuit will be under the control of the contacts 580 and 581 to shorten the pulse trains.

The pulse train generating equipment 543, which generates the pulses for operating the stepping motors 538 and 539, is exactly like the equipment 542 and controls power

applied to the hold line 533 of the switching units 512 and 513. The switching units 512 and 513 control the operation of the motor 586 through the relay 588 in the same manner that the switching units 510 and 511 control the operation of the motor 545 and detailed description thereof is not deemed necessary.

GRINDING HEAD ASSEMBLY

A grinding head and the supporting structure therefor adapted to be used in conjunction with the present invention is illustrated in Figs. 20, 21, and 22 and the four grinding heads may be arranged as indicated in Fig. 23.

Each grinding wheel 600 is carried by a movable carriage 602 mounted on a carriage bed 604 for rectilinear movements toward and away from the moving razor blade strip 10, generally normal to the plane of the bevel to be ground thereby, as better seen in Fig. 20.

The carriage 602 is a generally U-shaped structure with the drive shaft 606 for the grinding wheel journaled between the ends of the arms 607 and 608 and driven through drive pulleys 610 secured to one end of the shaft. A carriage adjusting mechanism 611 carried by the carriage 602 is connected to the bed 604 through a stationary feed screw 612 by means of a rotatable travelling, composite feed nut structure 614 threaded on the feed screw and adapted to be rotated by a shaft 618 journaled within a bracket 619 secured to the carriage by means of bolts 620. The carriage is mounted on the bed 604 by ball slides 622.

The feed screw 612 is mounted in a bracket 624 rigidly mounted on the carriage bed 604. The feed screw is provided with a shouldered mounting shank 625 that extends through the bracket 624 and is held in a fixed position by a clamping nut 626 threaded on the end 627 of the shank. A dial knob 628 is keyed to the shank 625 of the feed screw and is located between the clamping nut 626 and the bracket 624. The feed screw 612 may be manually adjusted by loosening the clamping nut 626, attaching a crank to the end of the shank 625 and rotating the feed screw as required and as indicated by the dial knob 628. After the desired adjustment has been made the locking nut 626 is drawn up tight against the dial knob 628.

The composite feed nut structure 614 comprises an internally threaded part 630 which is externally recessed to receive the hub 631 of a pinion 632 to which it is rigidly secured by means of bolts 633. The pinion 632 is journaled within the bridging section 609 of the carriage 602 by means of roller bearings 634 and 635. Another internally threaded part 636 of the composite feed nut structure 614 is keyed to the hub 631 of the pinion 632 by means of a key 640. The outer end of the feed nut part 636 is externally threaded to receive a clamping nut 642 for taking up any play that may have been developed by wear between the feed nut parts 630 and 636 with respect to the feed screw 612. A set screw 644 extending through the clamping nut 642 into the end of the hub 631 of the pinion 632 is provided for locating the clamping nut with respect to the pinion. One or more shims 646 are provided between the clamping nut 642 and the hub 631 of the pinion 632 for accurately setting the feed nut part 636 with respect to the part 630 to provide the desired no-play engagement with the feed screw 612. A retaining ring 648 surrounding the hub 631 of the pinion 632 is rigidly secured to the frame of the carriage 602 by bolts 649 and bears against the ball bearing 635. The pinion 632 is geared to a helical gear 650 secured to the lower end of the actuating shaft 618. Keyed to the shaft 618 near the upper end thereof is a spur gear 652 driven from the motor 539 by a pinion 654 mounted on the drive shaft of the motor. An auxiliary handwheel 656 is secured to the end of the shaft 618.

It will be appreciated that as the motor 539 is caused to rotate in one direction or the other in response to correction signals applied thereto from the grinding head control circuit (Fig. 19) described above, the pinion 654 will rotate the gear 652 and thereby impart rotation to the helical gear 650 which in turn will rotate the travelling composite feed nut structure 614 through the pinion 632. Rotation of the feed nut structure 614 will cause the latter and the entire carriage 602 to move in one direction or the other on the ball slides 622 depending upon the direction of rotation of the motor 539. The grinding wheel 600 carried by the carriage 602 will thus be moved either toward or away from the blade strip 10 supported by the blade strip guide and supporting structure generally indicated at 660.

The blade strip guide and supporting structure 660 includes a flat, vertically disposed carbide plate 662 having an outwardly extending horizontal ledge 663. The blade strip 10 runs along the flat vertical surface of a carbide plate 662, the lower edge of the strip being supported by the ledge 663. A blade strip retainer 664 having a shoulder resting on the ledge 663 of the carbide plate 662 is provided with a flat face that is disposed parallel to the face of the carbide plate and is secured to a supporting bracket 665 by means of screws 666. Grinding oil is sprayed onto the top edge of the blade strip 10 through a nozzle 668 by suitable piping to a source of grinding oil under pressure.

The blade strip 10 is held between the front face of the carbide plate 662 and the

parallel opposite face of the blade retainer 664 with sufficient firmness to prevent the blade strip from buckling under the pressure applied thereto by the grinding wheel 600 but sufficiently freely to permit movement of the blade strip through the guide.

The bracket 665 that carries the blade strip guide 660 and the nozzle 668 is rigidly secured to a base 669 which straddles the bed of the grinding machine and may be supported and clamped to the rigid rails 184 running along each side of the machine lengthwise thereof. The grinding wheel 600, the blade strip guide 660 and the nozzle 668 are enclosed within a housing 670 provided with a cover 672 that may be removed for visual inspection and adjustments. The carriage bed 604 is rigidly secured to the base 669 at the appropriate angle.

It will be appreciated from the above that the moving blade strip 10 is held in a predetermined position within the blade strip guide 660 with respect to the carriage 602, and that the grinding head 600 which is supported on the carriage can selectively be moved either toward the blade strip 10 or away from it by rotating the shaft 618 and hence the traveling feed nut structure 614 automatically through rotation of the motor 539 in response to signals from the control system described herein or manually by rotation of the hand wheel 656. The gear ratio of the gear train comprising the pinion 654, the spur gear 652, the helical gear 650, the pinion 632, the feed nut structure 614 and the feed screw 612 is selected so that a series of 16 pulses applied to the field windings of the motor 539 will cause the feed nut structure 614 and hence the grinding head 600 to be displaced about one ten-thousandth of an inch toward or away from the blade strip 10 depending on the sense of rotation of the motor. As explained above, the circuit that produces the motor actuating pulses may be modified to the extend of feeding 12 pulses instead of 16 to the motor 539 for each correction signal from the programmer and this will, of course, correspondingly reduce each discrete displacement step of the grinding head.

The grinding heads 1 and 3 that grind the two upper bevels are suitably inclined downwardly to the extent shown in Fig. 20 while the grinding heads 2 and 4 that grind the lower bevels are correspondingly inclined upwardly. A blade strip guide and supporting structure like the structure 660 but inverted may be used in grinding the lower bevels. The grinding heads for grinding the four bevels on the razor blade strip may suitably be arranged with respect to the moving razor blade strip as indicated in Fig. 23.

It will be noted from Fig. 23 that the unit 675 which comprises the optical scanners 11 and 12 and the half-width detector 23 associated with the upper half of the blade strip 10 is placed between grinding heads 3 and 4, and that unit 676 which comprises the optical scanners and the half-width detector associated with the lower half of the blade strip is placed beyond the grinding head 4. The operation of the control system is so correlated with the speed of the razor blade strip 10 that a portion of the blade strip ground by the grinding heads 1 and 3 after they have been corrected by correction signals derived from the unit 675 has been advanced to this unit before the next sampling is made. Similarly, a portion of the strip ground by the grinding heads 2 and 4 after they have been corrected in response to signals derived from the unit 676 will be advanced to this unit before the next sampling is made.

Although only a specific embodiment of the invention has been described herein, it is not intended to limit the invention solely thereto, but to include all of the obvious variations and modifications within the spirit and scope of this invention.

WHAT I CLAIM IS:—

1. Method of automatically grinding an edge on a moving metal strip, comprising the steps of scanning each of two adjacent ground bevels on the strip and producing a signal from each scan as a function of the width of the bevel, comparing the signals derived from the respective bevels and producing an error signal as a function of the difference in the widths of the bevels, producing grinding head control signals from the error signal, and applying said control signals to grinding head positioning means in accordance with a predetermined program to adjust the positions of the grinding heads as required to reduce the error signal.

2. Method according to claim 1, wherein one measures the lateral distance from the edge to a reference point on the strip, produces a second error signal as a function of deviations from a predetermined desired value of this distance, and uses the second error signal together with the first-mentioned error signals in the production of the grinding head control signals so that the positions of the grinding heads are adjusted as required to reduce simultaneously the errors in bevel width and strip width.

3. Method according to claim 2, wherein one uses as the reference point a point defined by a longitudinal perforation in the strip.

4. Method according to any one of claims 1 to 3, wherein the scanning of the bevels is performed by illuminating the bevels and forming a reflected image thereof, by masking the edge portion of each bevel image, and by scanning each of the bevel images between the heel and the

masked portions thereof, the signal produced from each scan corresponding in width to the duration of the scan in traversing the exposed bevel portion.

5. Method according to claim 4, wherein the scanning of the bevels is performed repeatedly at a predetermined rate, and the signal from each scan is produced by detecting the changes in the intensity of reflected light resulting from the traversing.

6. Method according to any one of claims 1 to 5, for automatically controlling the grinding of edges on the opposite sides of the moving strip, wherein the scanning and comparing steps are performed simultaneously for the bevels of both edges, while the production of grinding head control signals and the application thereof to positioning means for the grinding heads are performed first for the bevels of one edge, then for the bevels of the other edge, in an alternate manner.

7. Apparatus for automatically grinding an edge on a moving metal strip in which a grinding machine is provided having grinding heads disposed to form two adjacent bevels on the edge, comprising signal producing scanning means which scan each bevel and produce a signal from each scan as a function of the width of the bevel, the scanning means being coupled to signal producing comparing means which compare the signals derived from the respective bevels and produce an error signal as a function of the difference in the widths of the bevels, the comparing means being coupled to a programmer which produces grinding head control signals from the error signal and applies these control signals to grinding head positioning means in accordance with a predetermined program to adjust the positions of the grinding heads as required to reduce the error signal.

8. Apparatus according to claim 7, wherein the scanning means comprises means which sense a width parameter of each bevel, means which respond to each sensing means to produce a series of electrical signal pulses each of which has a detectable portion proportional respectively to one of said width parameters, separate means which detect and amplify the signal pulses of each of said series to produce for each of said width parameters a unique series of amplified rectangular wave pulses corresponding in width to said respective detectable portions, means which clip the rectangular wave pulses of each such series to a predetermined amplitude, and means which integrate said clipped rectangular wave pulses and thereby produce a d.c. potential representing the average of the width-potential product of said series, the d.c. potentials being supplied to said comparing means as the signals derived from the respective bevels.

9. Apparatus according to claim 7 or 8, wherein the programmer is further responsively coupled to means which measure the lateral distance from a reference point on said strip to the edge thereof and which produce error signals when this distance deviates from a predetermined value.

10. Apparatus according to claim 9, wherein the lateral distance measuring means is such as to produce an a.c. error signal whose phase and amplitude represents the sense and magnitude of the deviation, this signal being mixed with an a.c. signal of the same frequency whose phase and amplitude are manually adjustable, whereby the effective null point of the lateral distance measuring means may be adjusted.

11. Apparatus according to any one of claims 7 to 10, wherein the strip is provided with spaced, elongated apertures which are aligned in the length direction of the strip, the strip being supported by a pair of elements having juxtaposed flat, parallel surfaces spaced by a distance sufficient to permit the strip to pass therebetween, one of said surfaces having an elongated blade supporting projection which is received within an elongated groove in the other surface, the projection having a flat side surface and tapered end surfaces and having a width which permits it to pass through the apertures of the strip, the projection being spaced from adjacent surfaces of the groove so as to permit the solid portions of the strip separating the apertures to bend about the projection, the flat side surface of the projection engaging one longitudinal edge of the apertures.

12. A method of automatically grinding an edge on a moving metal strip, substantially as herein described.

13. Apparatus for automatically grinding an edge on a moving metal strip, constructed and arranged substantially as herein described with reference to the accompanying drawings.

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Sheerness: Printed for Her Majesty's Stationery Office, by Smiths Printers and Duplicators. 1968.
Published at the Patent Office, 25 Southampton Buildings, London, W.C.2, from which copies may be obtained.

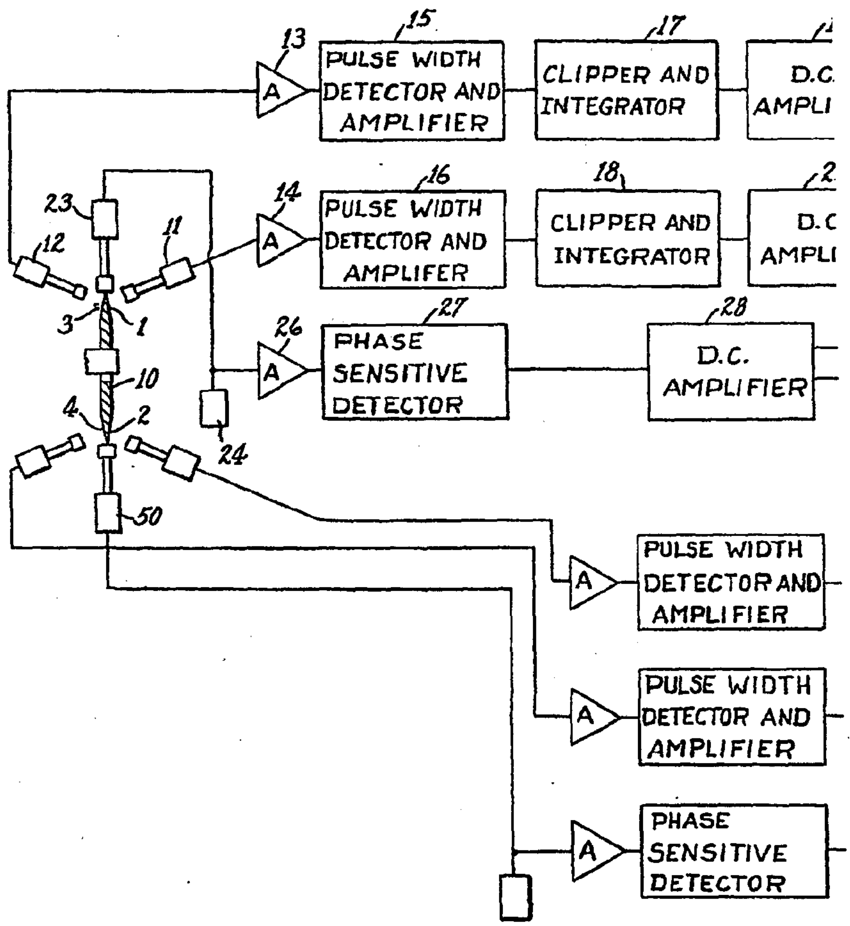
PULSE WIDTH DETECTOR AND AMPLIFIER
CLIPPER AND INTEGRATOR
D.C. AMPLI
PULSE WIDTH DETECTOR AND AMPLIFER
CLIPPER AND INTEGRATOR
PHASE SENSITIVE DETECTOR
D.C. AMPLIFIER
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Fig.1

1102041 COMPLETE SPECIFICATION

11 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

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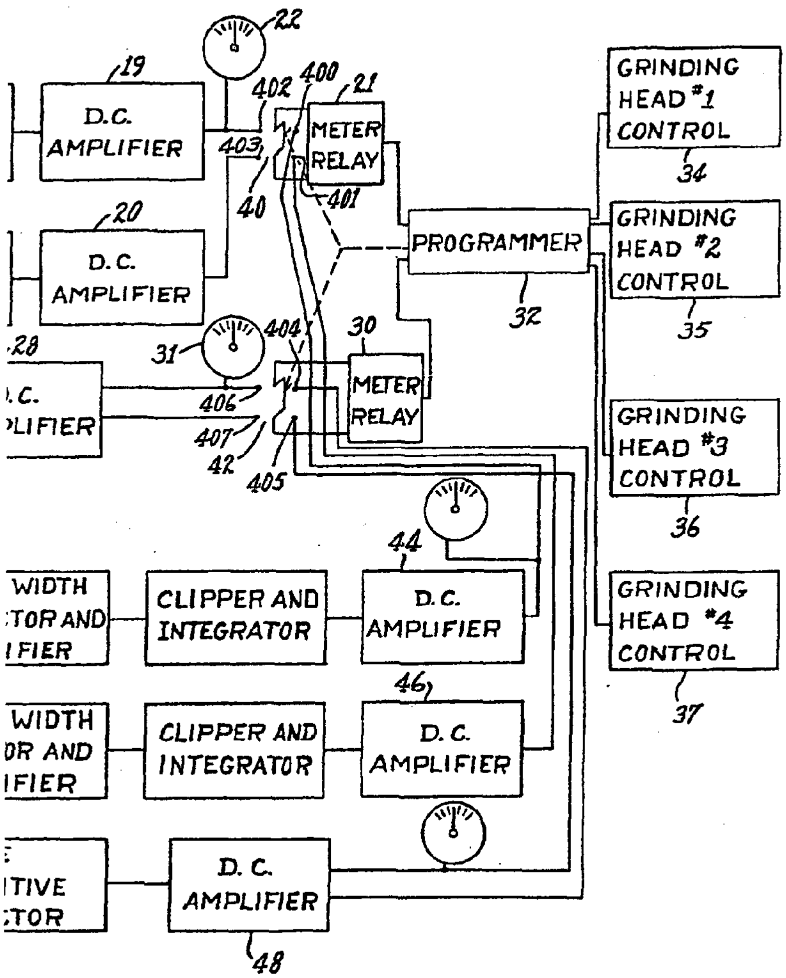
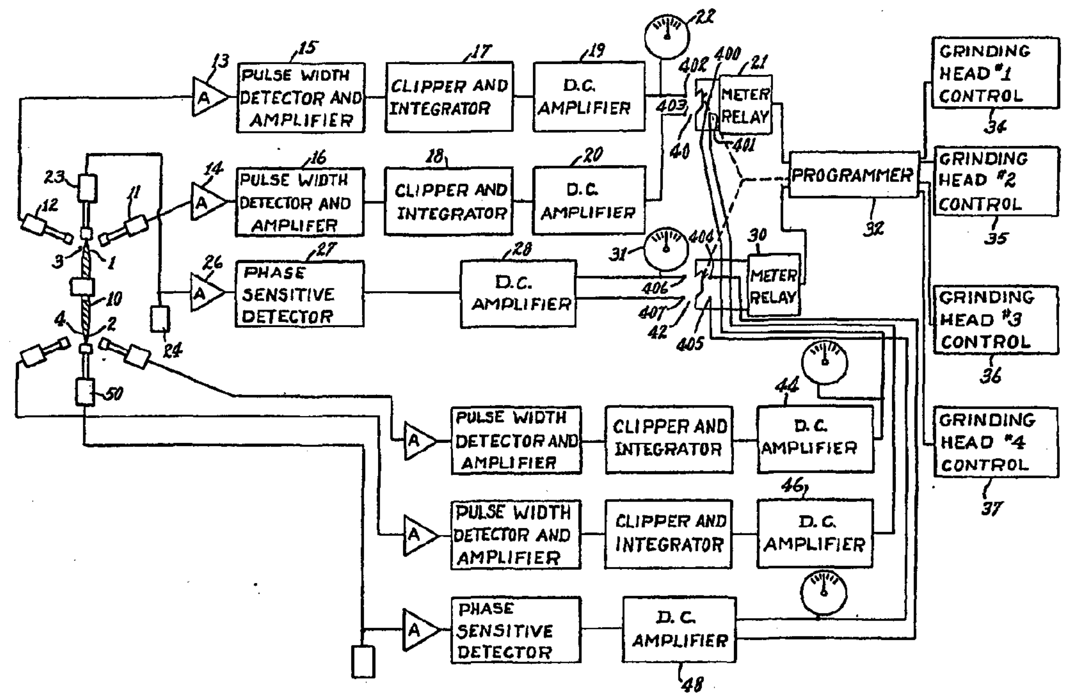


Fig.1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CLIPPER AND INTEGRATOR
D.C. AMPLIFIER
METER RELAY
PROGRAMMER
PHASE SENSITIVE DETECTOR
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GRINDING HEAD #2 CONTROL
GRINDING HEAD #3 CONTROL
GRINDING HEAD #4 CONTROL
A

Fig.1

Fig. 2

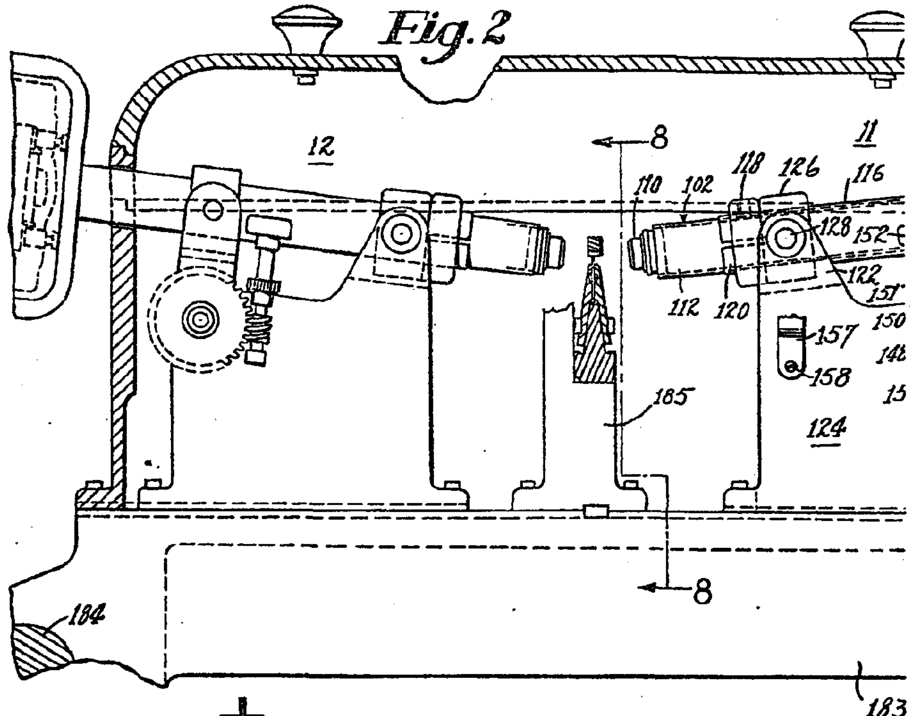

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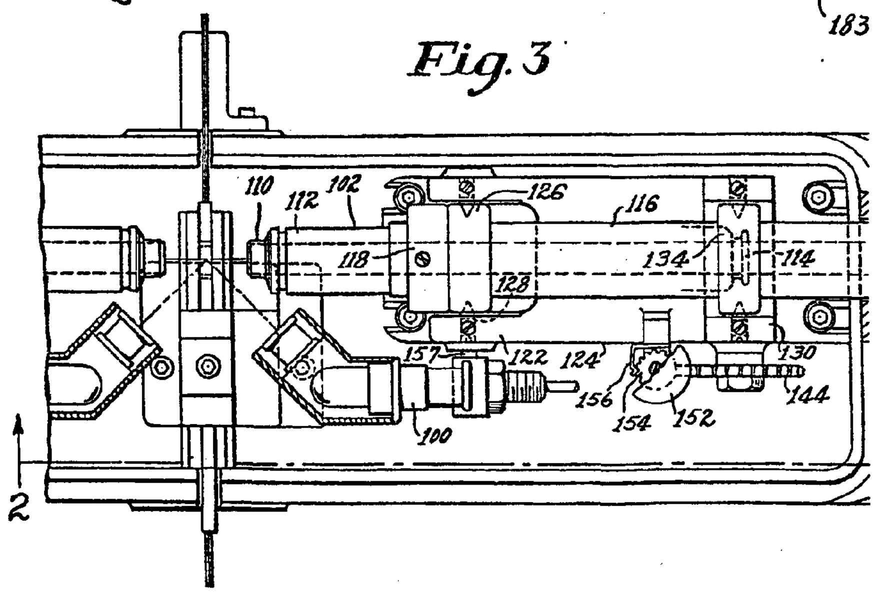
Fig. 3



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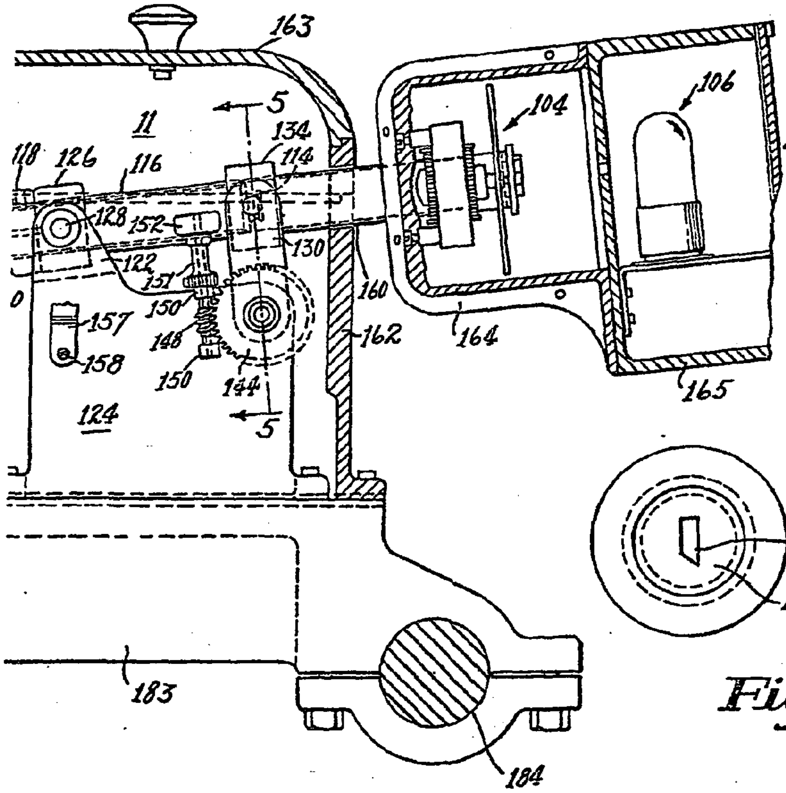
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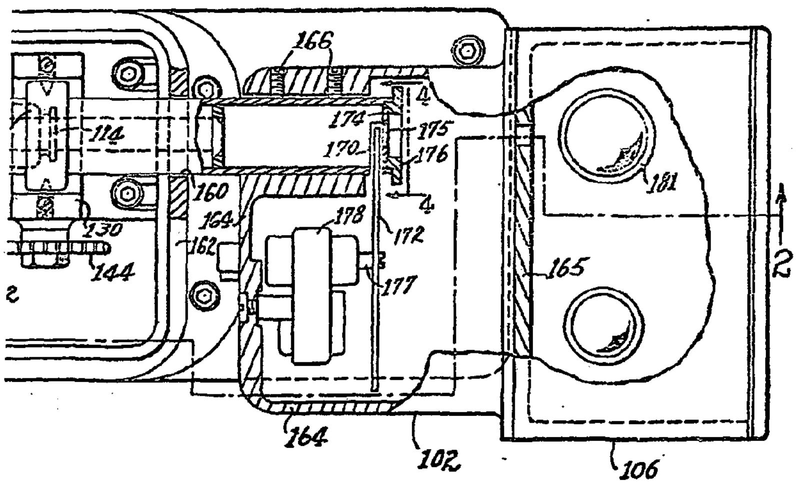
Fig. 4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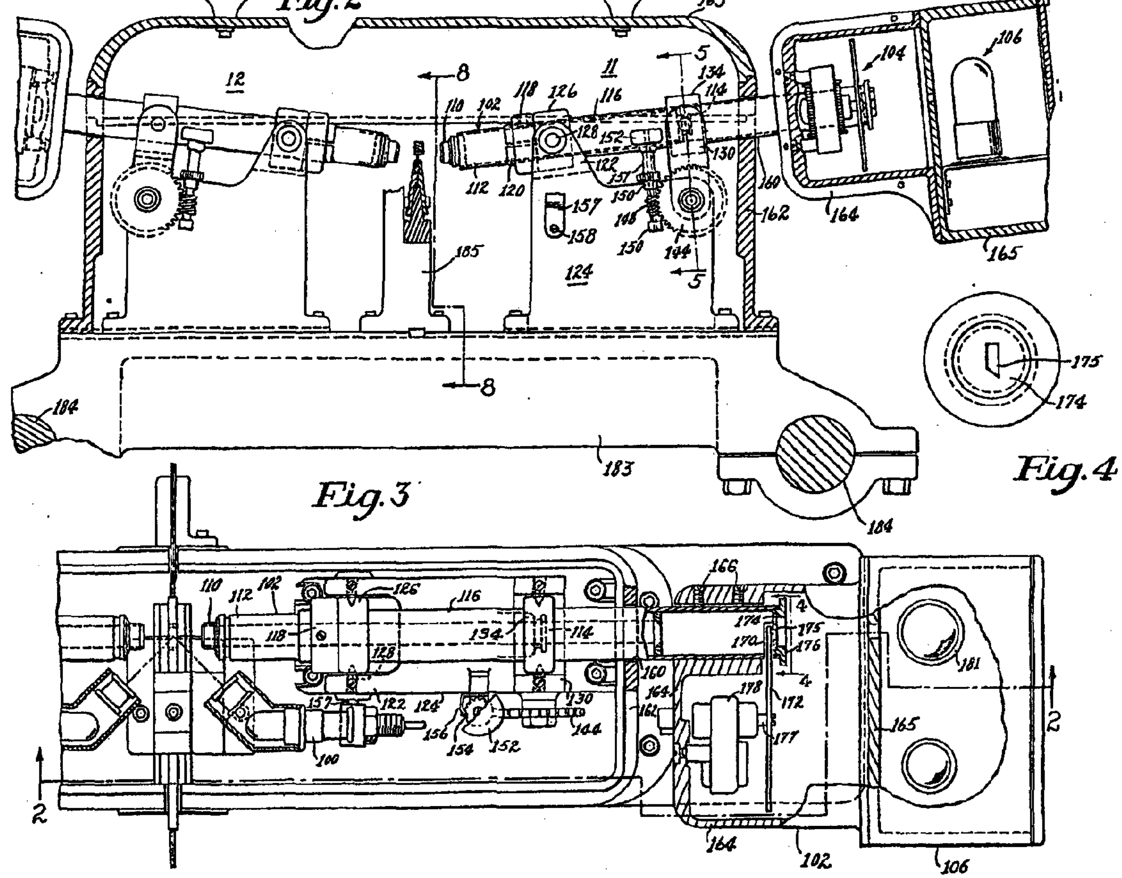

Fig. 2

Fig. 4

Fig. 3

Fig.5

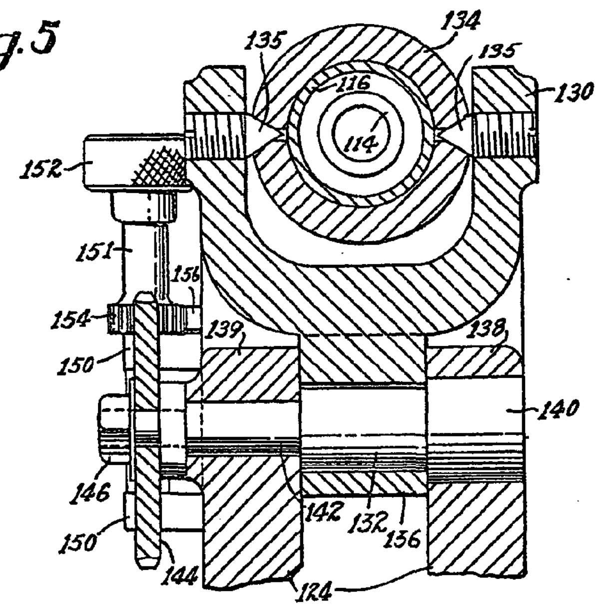
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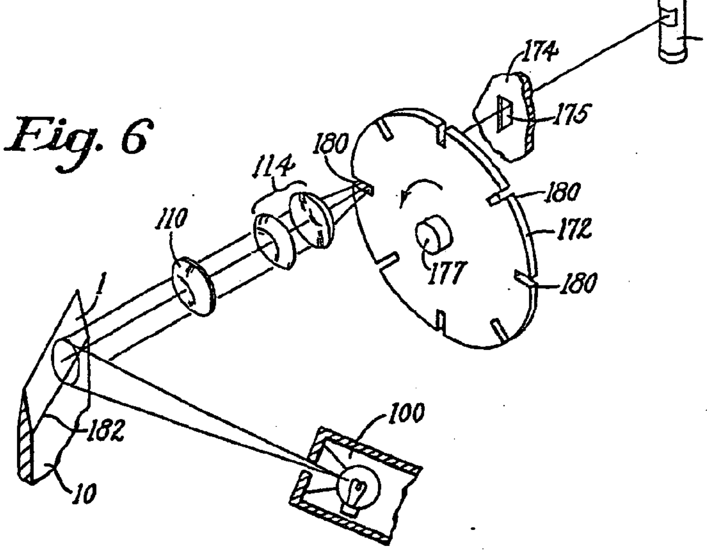
Fig. 6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Sheet 3

Fig. 7

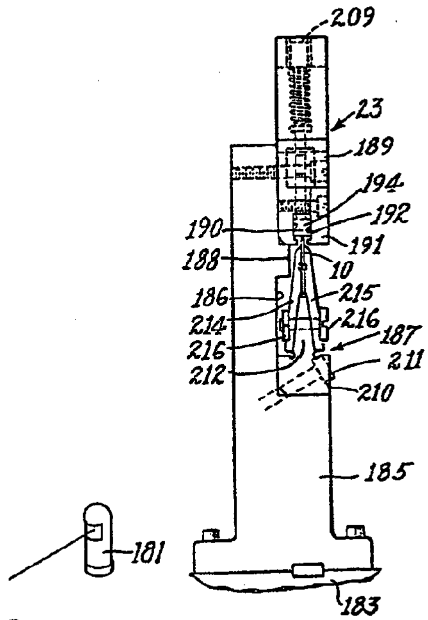
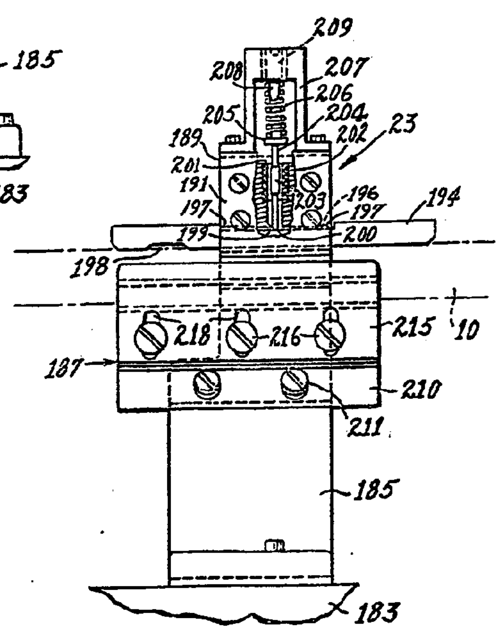


Fig. 8



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11 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 3

Fig.5

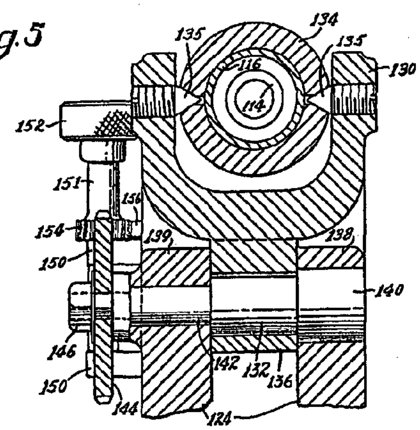


Fig.7

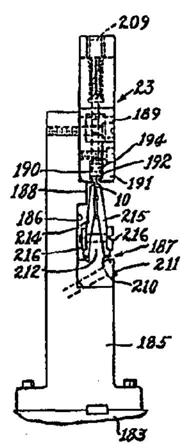


Fig. 6

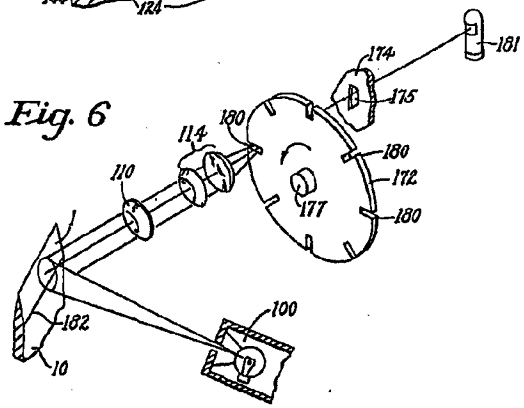


Fig.8

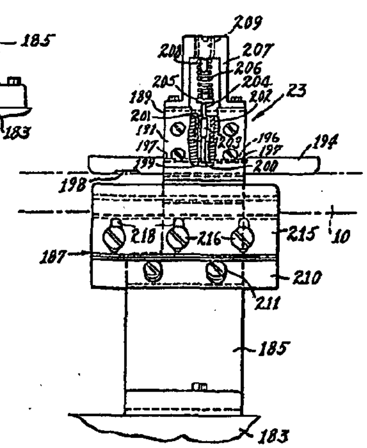


Fig.9

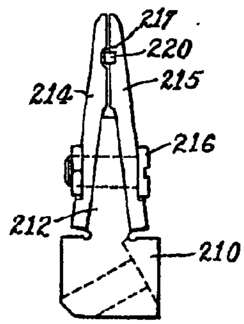
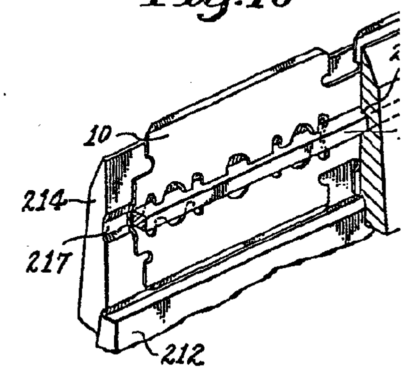
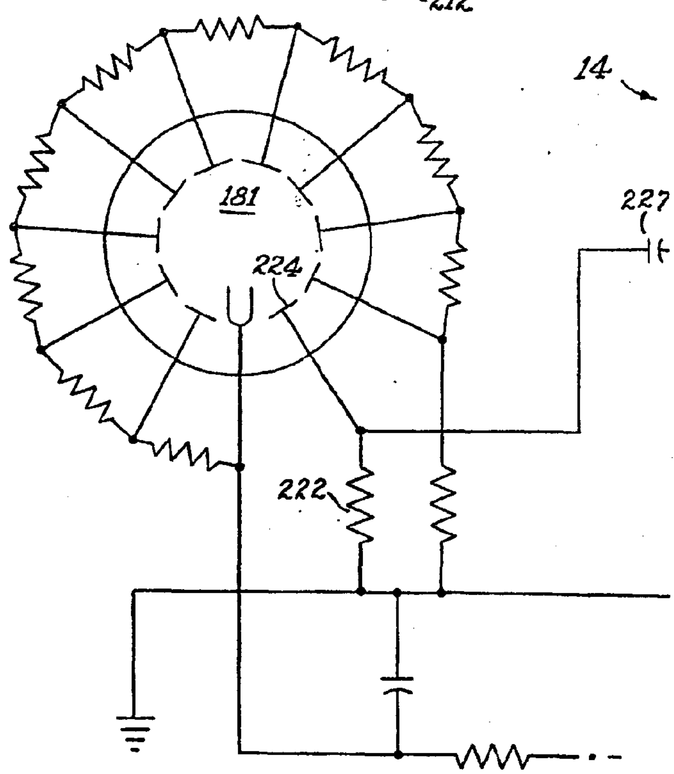


Fig.10





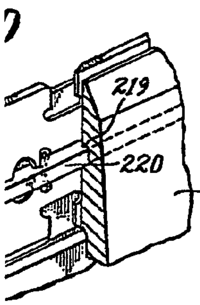
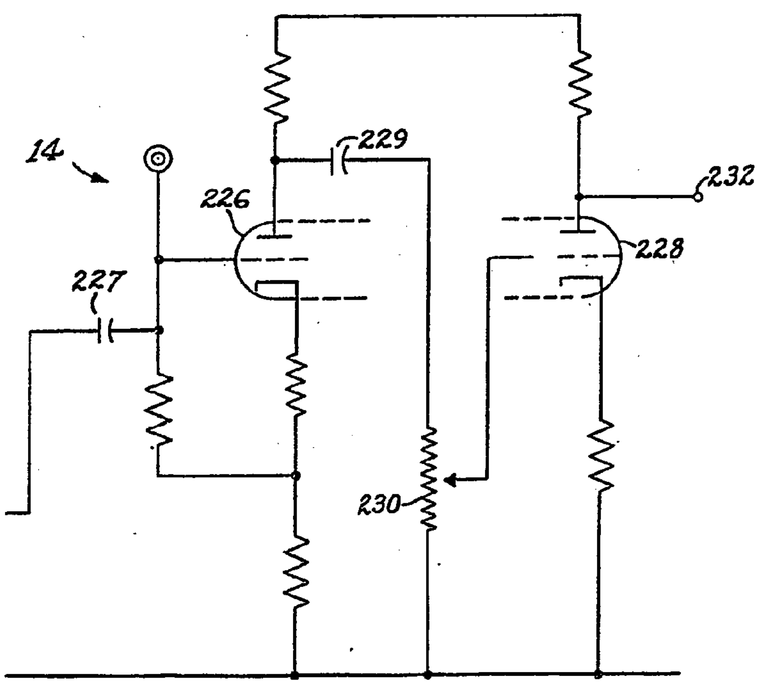


Fig. 11



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Sheet 4

Fig.9

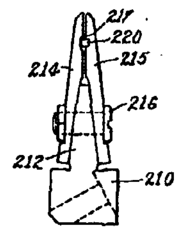


Fig.10

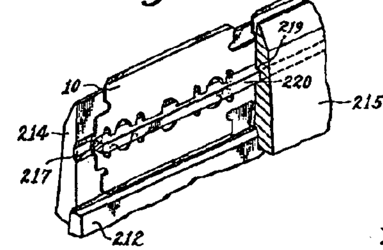
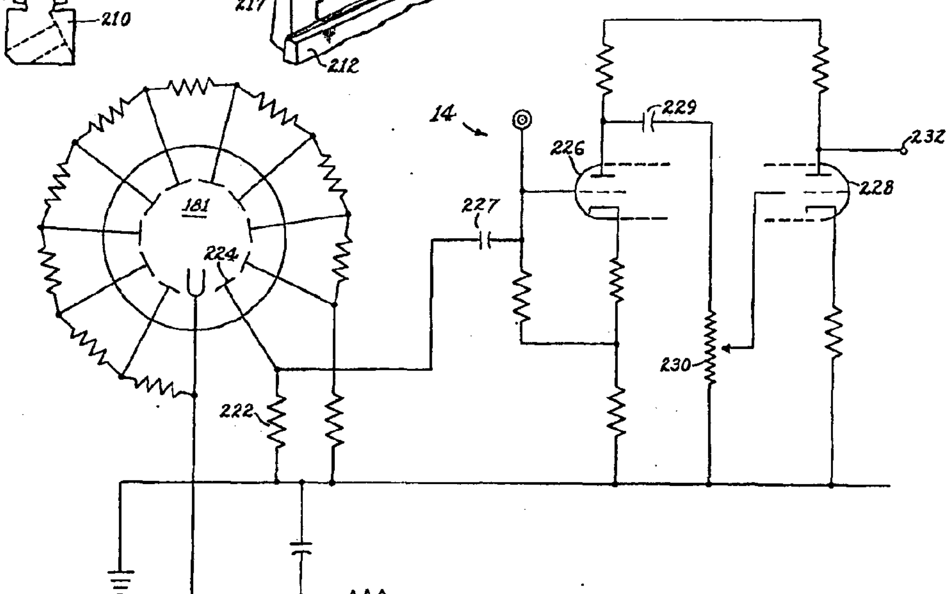


Fig.11



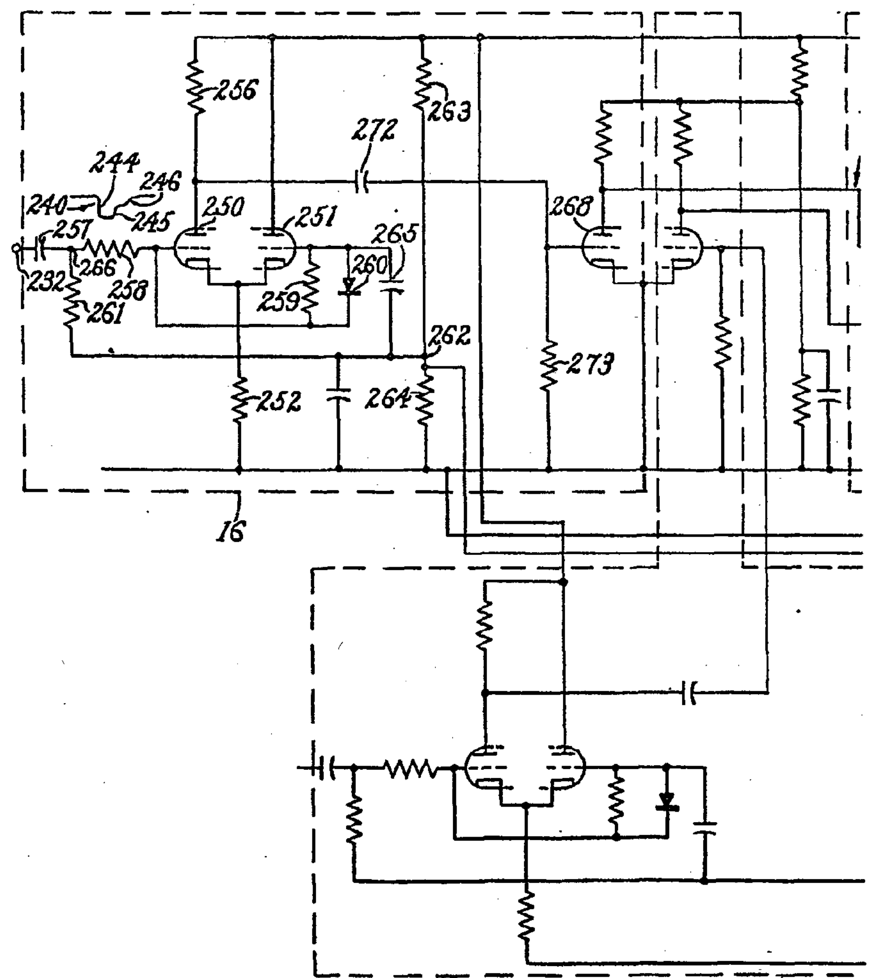


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Fig. 12

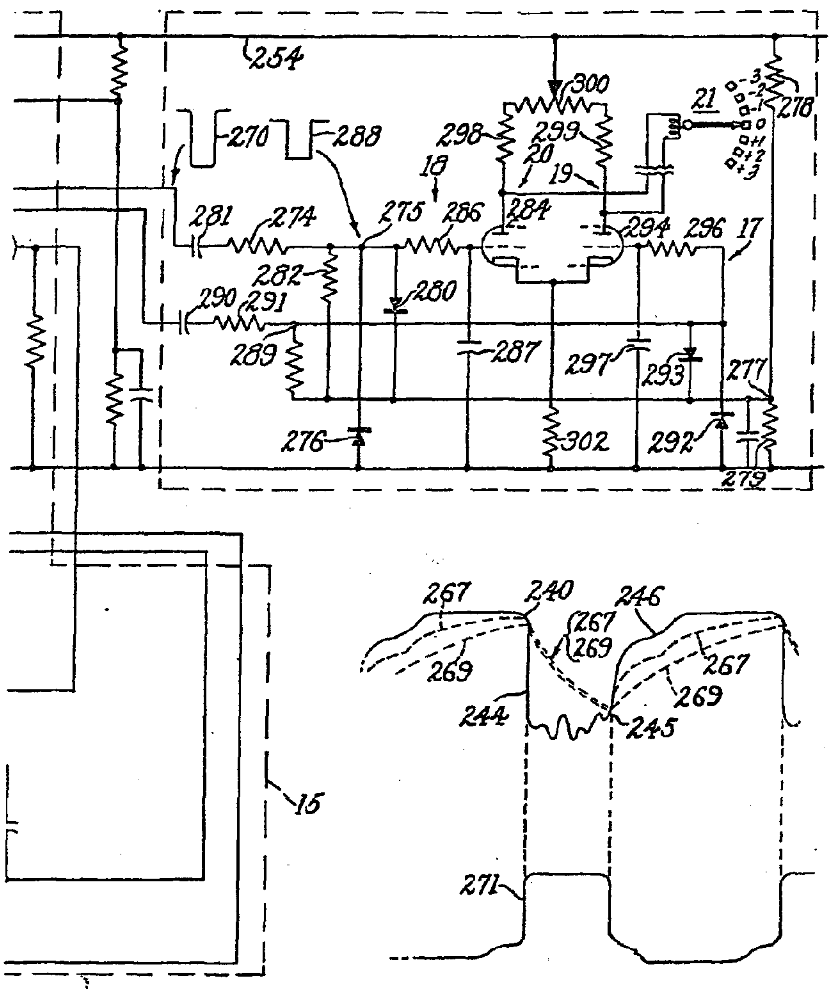
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Fig. 12 A

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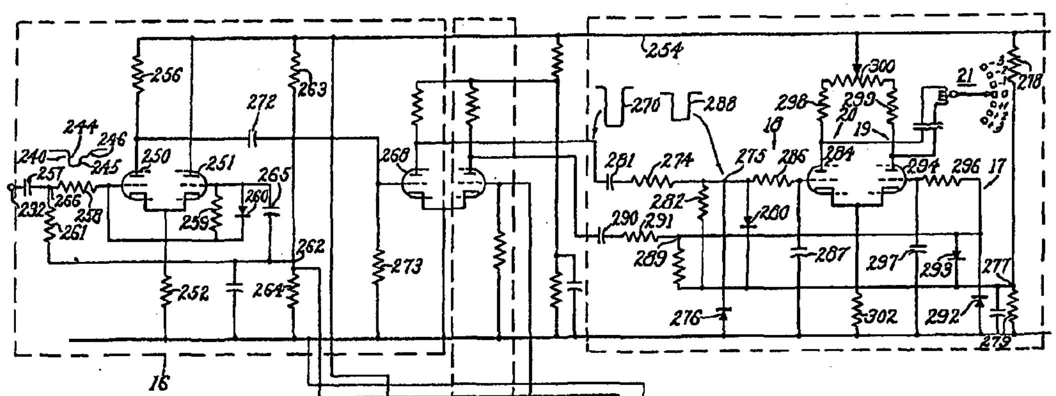

Fig. 12

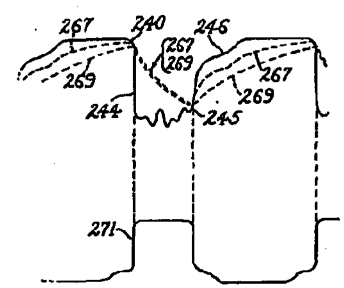

Fig. 12A

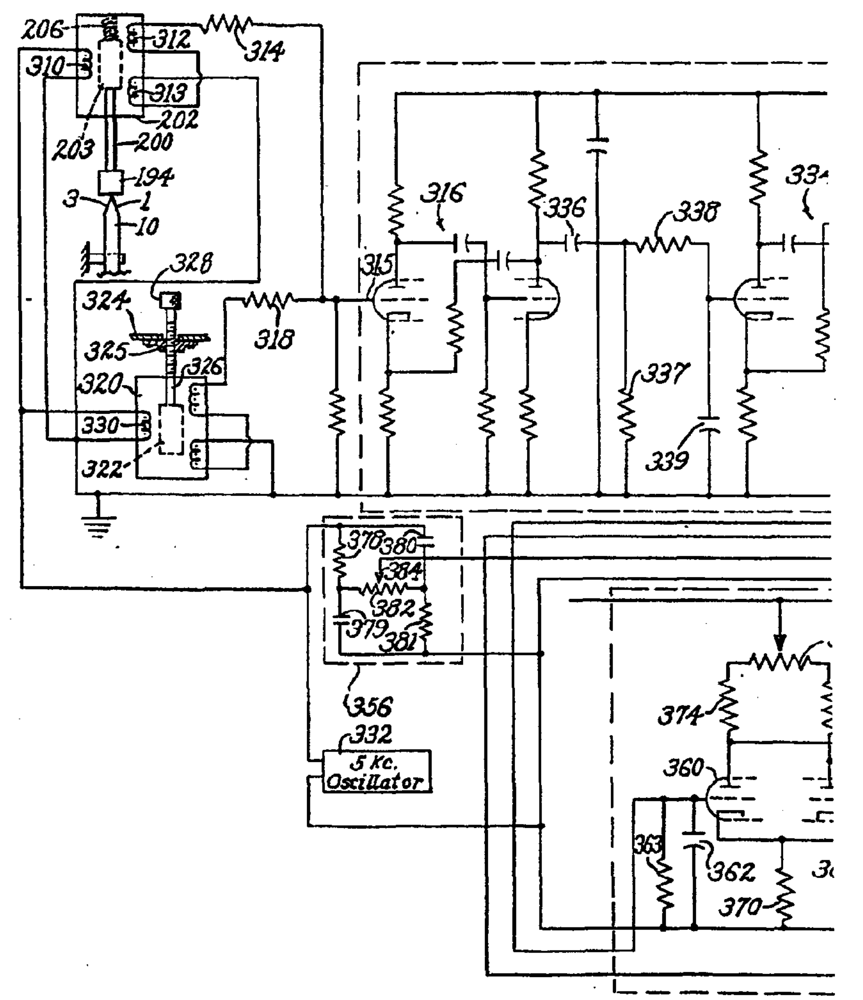

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Fig.

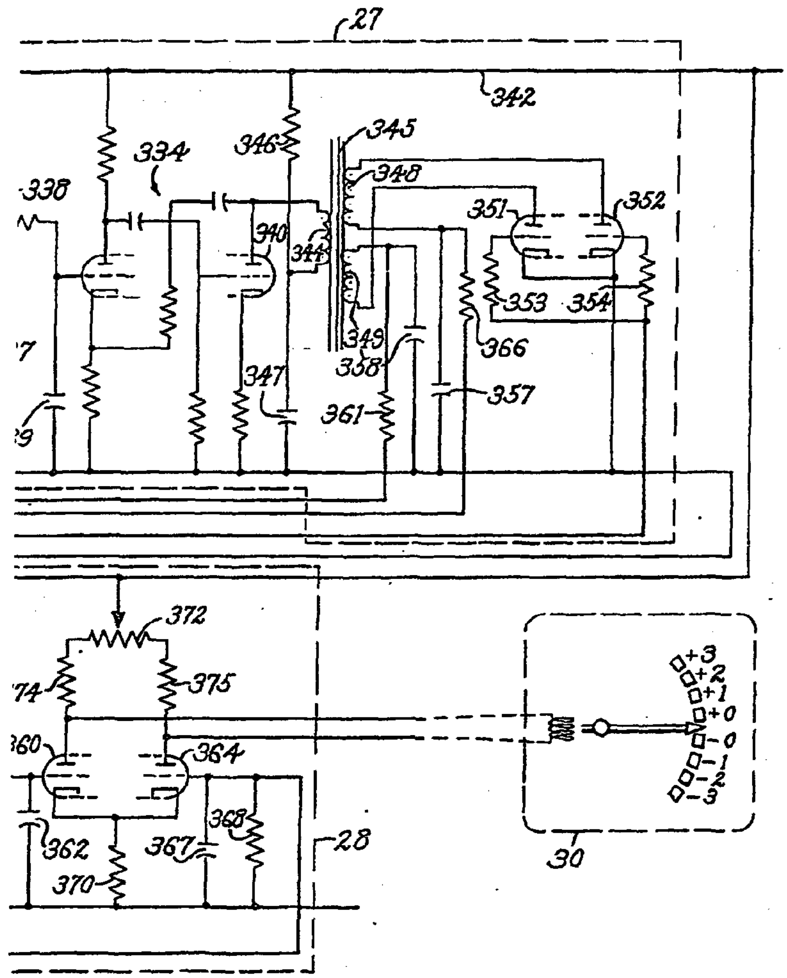
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Fig. 13

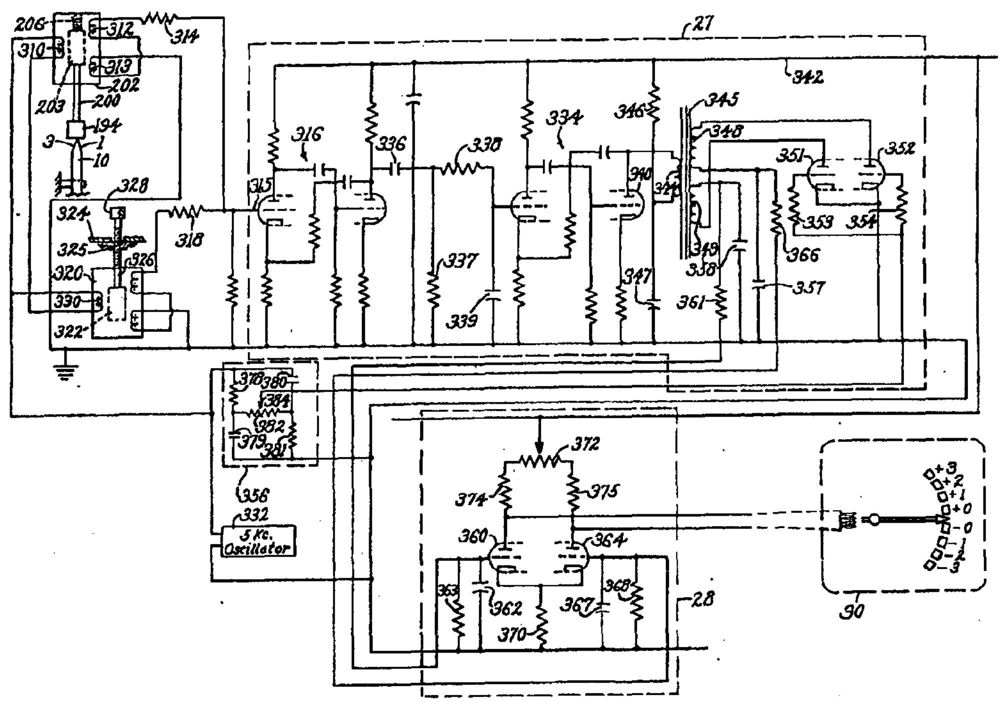
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Fig. 13

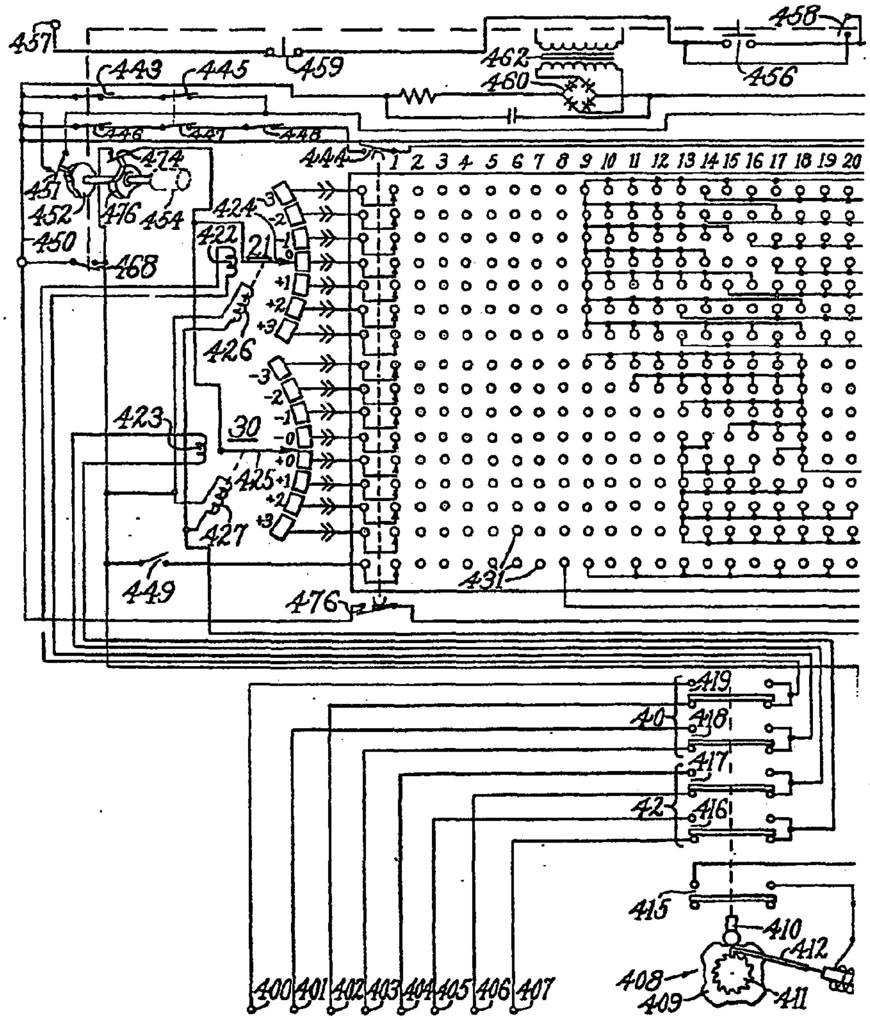
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Fig. 14

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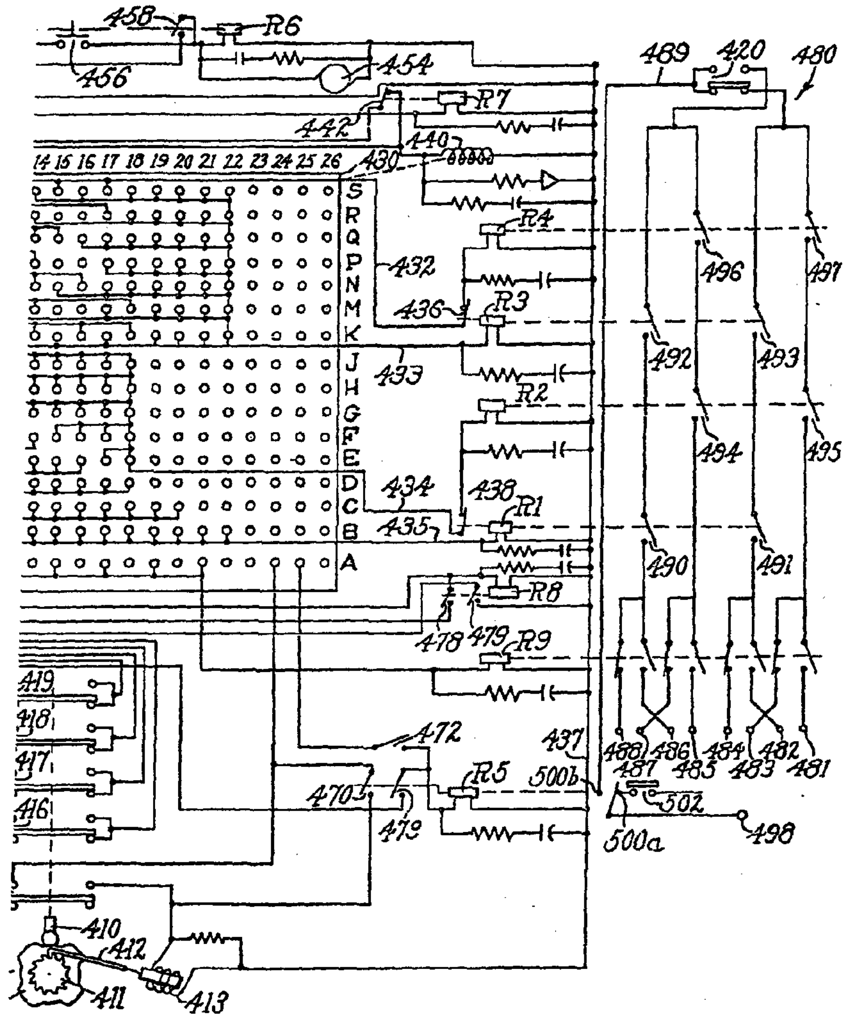

Fig.14

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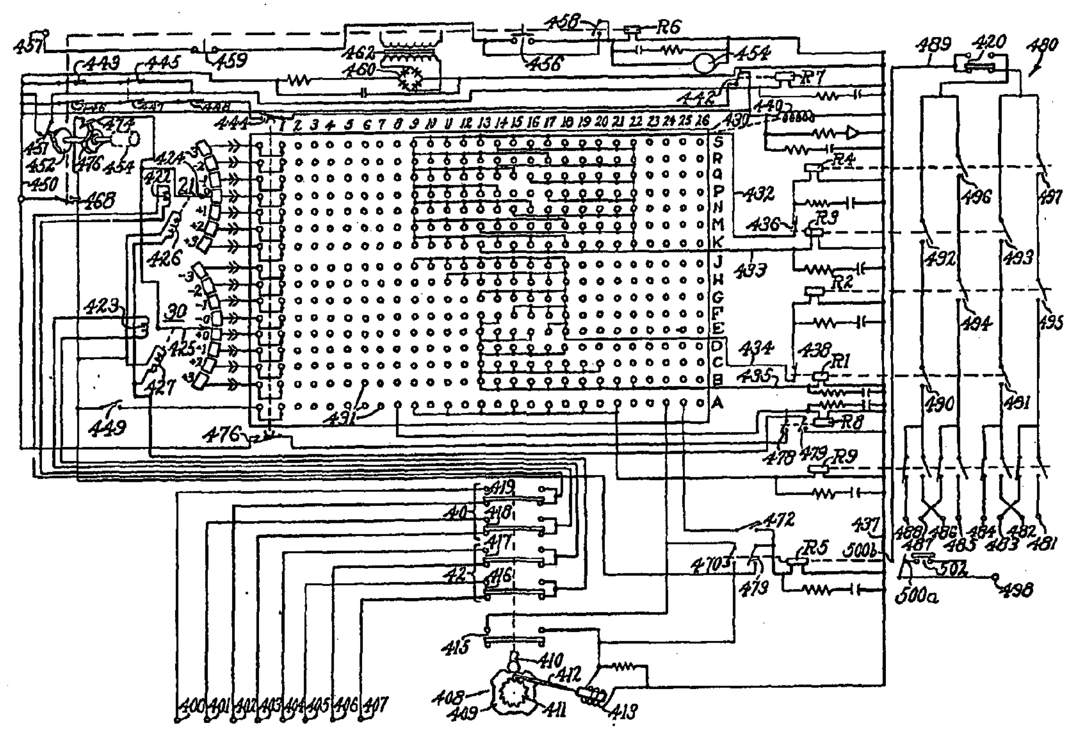
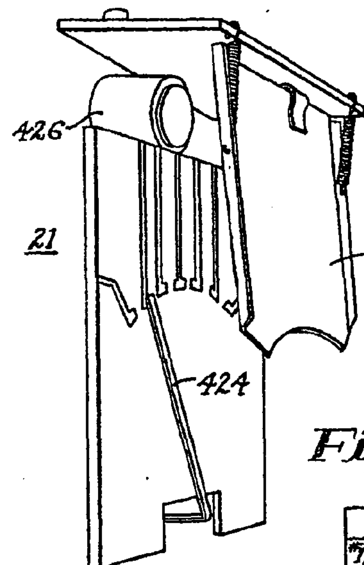


Fig.14

Fig. 15



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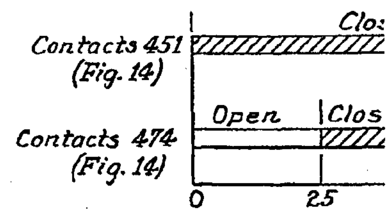

Fig. 17

Too Large — Deffect

(Deflection of Meter Relay 21)	+3 #1 Head	+3 #3 Head	+2 #1 Head	+2 #3 Head	+1 #1 Head	+1 #3 Head	+0 #1 Head
+3	5 IN	2 IN	4 IN	1 IN	3 IN	0	2 IN
+2	4 IN	2 IN	3 IN	1 IN	2 IN	0	1 IN
+1	4 IN	3 IN	3 IN	2 IN	2 IN	1 IN	1 IN
0	3 IN	3 IN	2 IN	2 IN	1 IN	1 IN	0
−1	3 IN	4 IN	2 IN	3 IN	1 IN	2 IN	0
−2	2 IN	4 IN	1 IN	3 IN	0	2 IN	1 OUT
−3	2 IN	5 IN	1 IN	4 IN	0	3 IN	1 OUT

Too Small ↑ Bevels 1 and 3 ↓ Too Large

GRINDING HEA

1102041 COMPLETE SPECIFICATION

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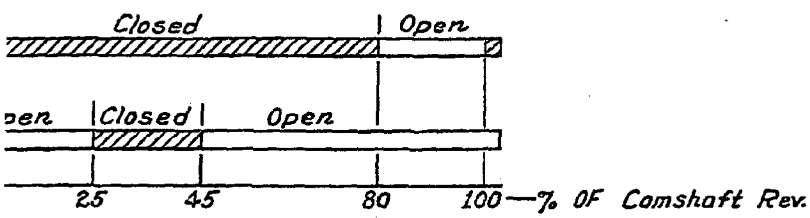
Sheet 8



Half Width

Deflection of Meter Relay 30 Too Small

	+0		−0		−1		−2		−3	
#3 Head	#1 Head	#3 Head	#1 Head	#3 Head	#1 Head	#3 Head	#1 Head	#3 Head	#1 Head	#3 Head
0	2 IN	1 OUT	1 IN	2 OUT	0	3 OUT	1 OUT	4 OUT	2 OUT	5 OUT
0	1 IN	1 OUT	1 IN	1 OUT	0	2 OUT	1 OUT	3 OUT	2 OUT	4 OUT
1 IN	1 IN	0	0	1 OUT	1 OUT	2 OUT	2 OUT	3 OUT	3 OUT	4 OUT
1 IN	0	0	0	0	1 OUT	1 OUT	2 OUT	2 OUT	3 OUT	3 OUT
2 IN	0	1 IN	1 OUT	0	2 OUT	1 OUT	3 OUT	2 OUT	4 OUT	3 OUT
2 IN	1 OUT	1 IN	1 OUT	1 IN	2 OUT	0	3 OUT	1 OUT	4 OUT	2 OUT
3 IN	1 OUT	2 IN	2 OUT	1 IN	3 OUT	0	4 OUT	1 OUT	5 OUT	2 OUT

NG HEAD CORRECTION CHART

Fig. 15

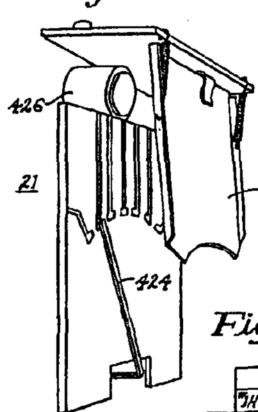


Fig. 16

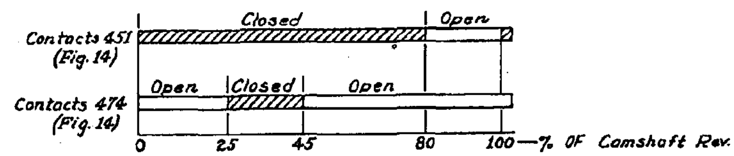
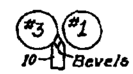


Fig. 17

Half Width

Too Large ← Deflection of Meter Relay 30 → Too Small



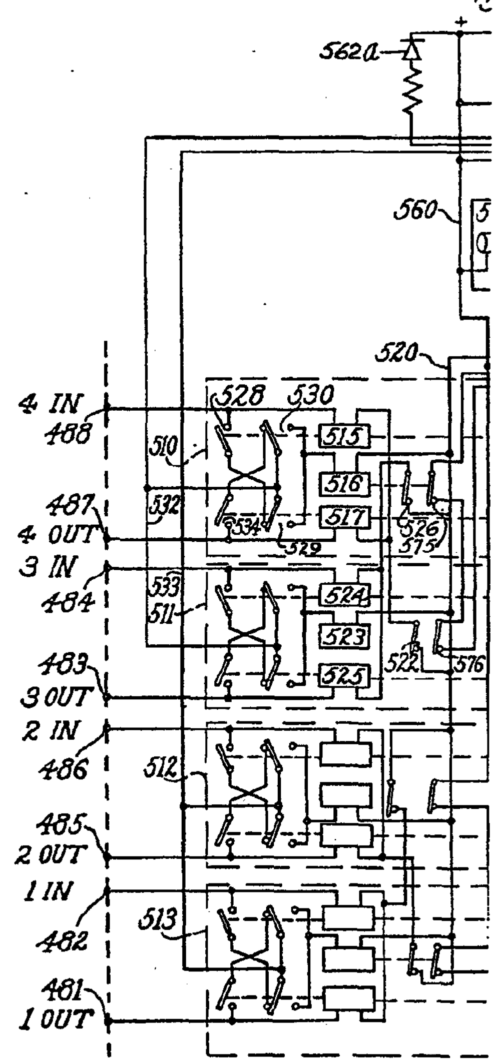
Too Small ↑ Bevels 1 and 3 ↓ Too Large

(Deflection of Meter Relay 21)

	+3		+2		+1		+0		−0		−1		−2		−3	
	#1 Head	#3 Head	#1 Head	#3 Head	#1 Head	#3 Head	#1 Head	#3 Head	#1 Head	#3 Head	#1 Head	#3 Head	#1 Head	#3 Head	#1 Head	#3 Head
+3	5 IN	2 IN	4 IN	1 IN	3 IN	0	2 IN	1 OUT	1 IN	2 OUT	0	3 OUT	1 OUT	4 OUT	2 OUT	5 OUT
+2	4 IN	2 IN	3 IN	1 IN	2 IN	0	1 IN	1 OUT	1 IN	1 OUT	0	2 OUT	1 OUT	3 OUT	2 OUT	4 OUT
+1	4 IN	3 IN	3 IN	2 IN	2 IN	1 IN	1 IN	0	0	1 OUT	1 OUT	2 OUT	2 OUT	3 OUT	3 OUT	4 OUT
0	3 IN	3 IN	2 IN	2 IN	1 IN	1 IN	0	0	0	0	1 OUT	1 OUT	2 OUT	2 OUT	3 OUT	3 OUT
−1	3 IN	4 IN	2 IN	3 IN	1 IN	2 IN	0	1 IN	1 OUT	0	2 OUT	1 OUT	3 OUT	2 OUT	4 OUT	3 OUT
−2	2 IN	4 IN	1 IN	3 IN	0	2 IN	1 OUT	1 IN	1 OUT	1 IN	2 OUT	0	3 OUT	1 OUT	4 OUT	2 OUT
−3	2 IN	5 IN	1 IN	4 IN	0	3 IN	1 OUT	2 IN	2 OUT	1 IN	3 OUT	0	4 OUT	1 OUT	5 OUT	2 OUT

GRINDING HEAD CORRECTION CHART

Fig.18



562a
560
520
4 IN
488
528
530
510
515
516
517
532
534
529
526
375
487
4 OUT
3 IN
484
533
511
524
523
525
522
576
483
3 OUT
2 IN
486
512
485
2 OUT
1 IN
482
513
481
1 OUT

1102041 COMPLETE SPECIFICATION

11 SHEETS This drawing is a reproduction of the Original on a reduced scale

Sheet 9

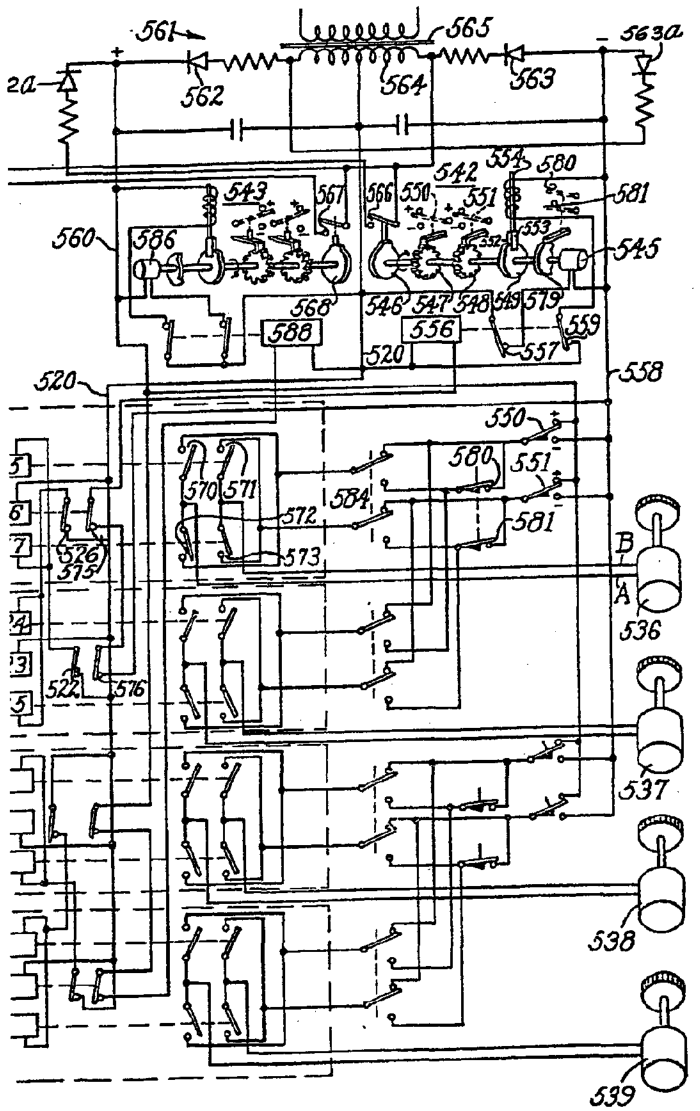


Fig.18

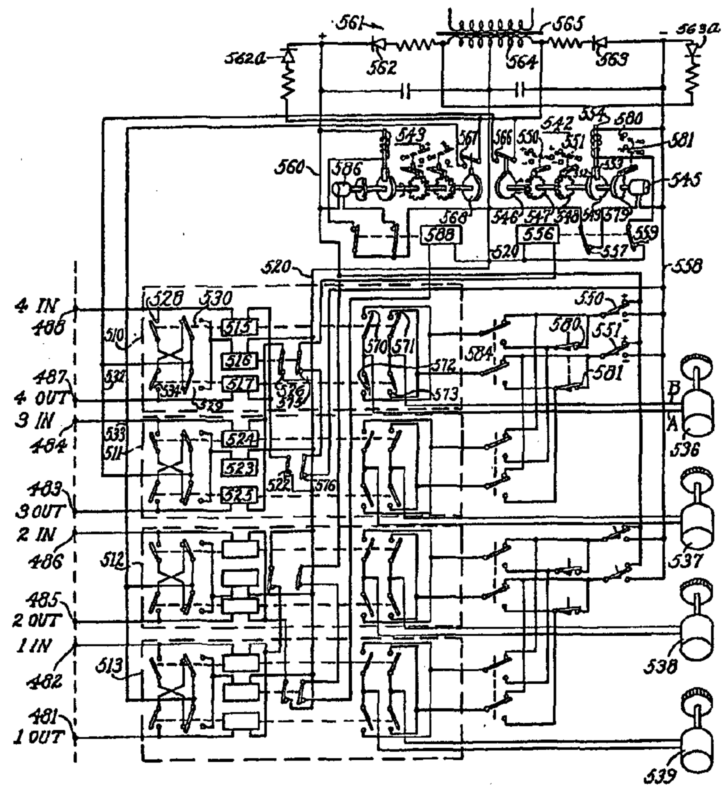
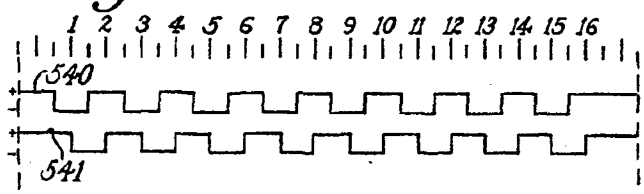

561
565
563a
562a
562
564
563
543
567
566
550
542
554
580
581
560
586
545
568
546
547
548
549
579
559
588
556
520
557
558
520
4 IN
488
528
530
515
510
516
532
517
487
4 OUT
534
529
576
519
3 IN
533
524
484
511
523
483
522
525
576
3 OUT
2 IN
486
512
485
2 OUT
1 IN
482
513
481
1 OUT
570
571
572
573
584
550
580
551
581
B
A
536
537
538
539

Fig. 19


1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
540
541

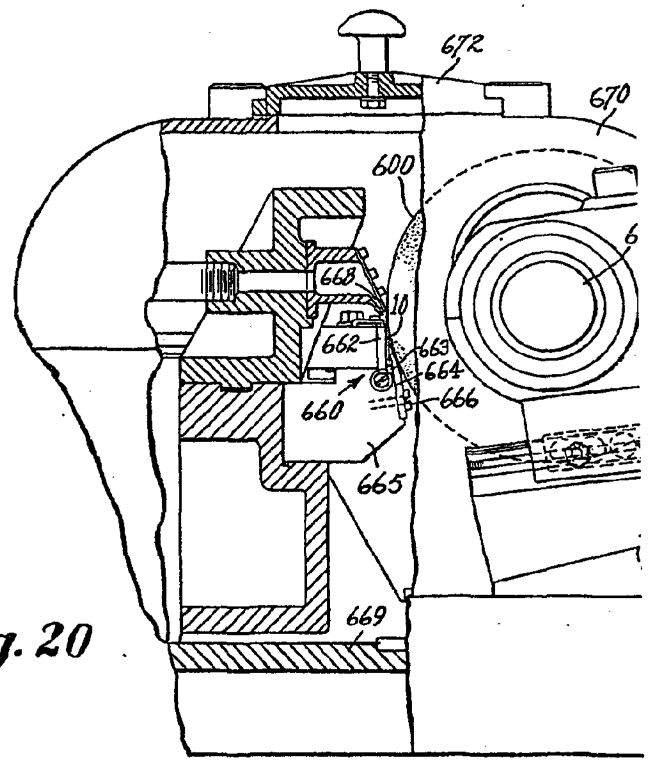
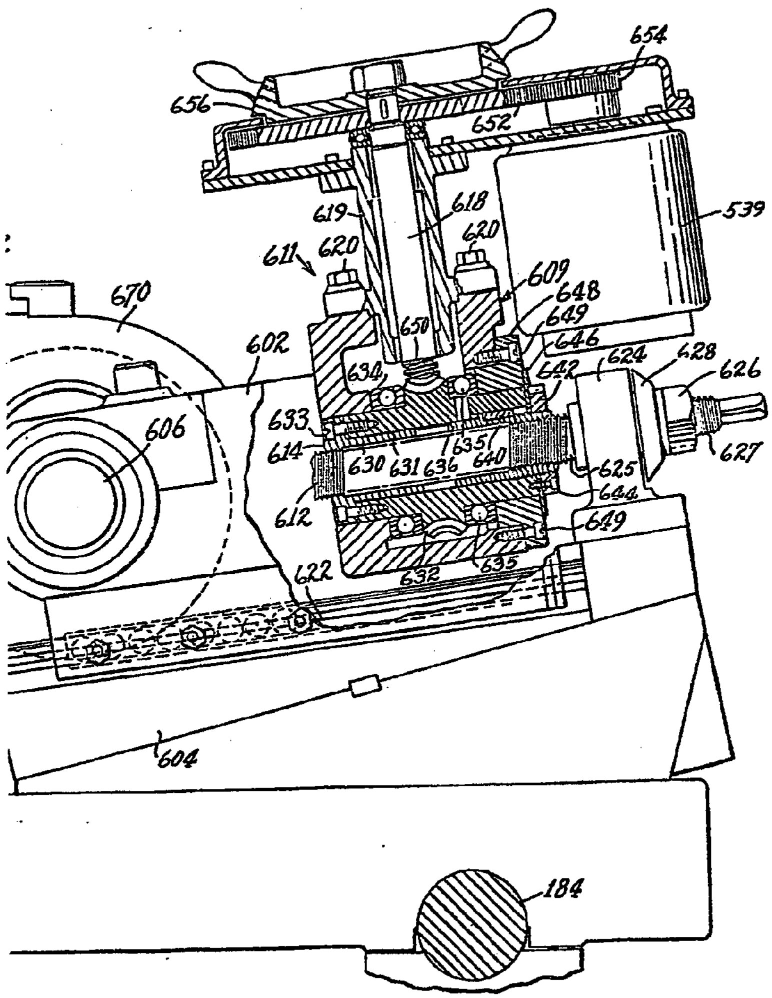

672
670
600
668
10
662
663
664
666
660
665
669

Fig. 20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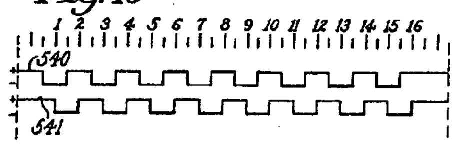
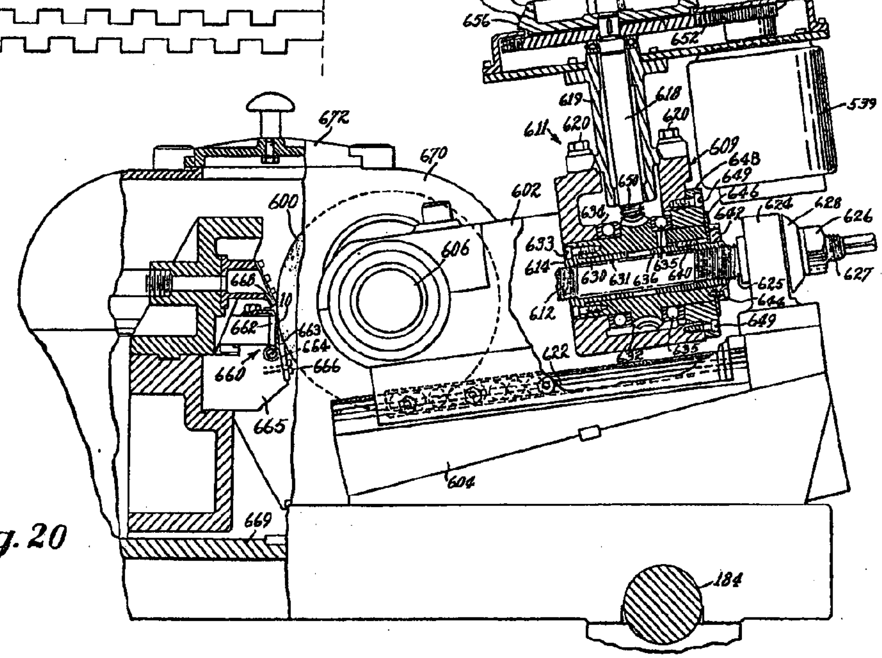
656
652
539
619
618
620
611
620
609
648
670
649
650
646
602
624
628
634
626
642
633
606
614
630
631
635
636
640
625
627
644
612
649
622
632
635
604
184

Fig. 19


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
540
541


654
656
652
539
619
618
620
611
620
609
648
649
646
672
670
602
650
634
642
624
628
626
600
606
633
614
630
631
636
635
640
627
625
644
668
10
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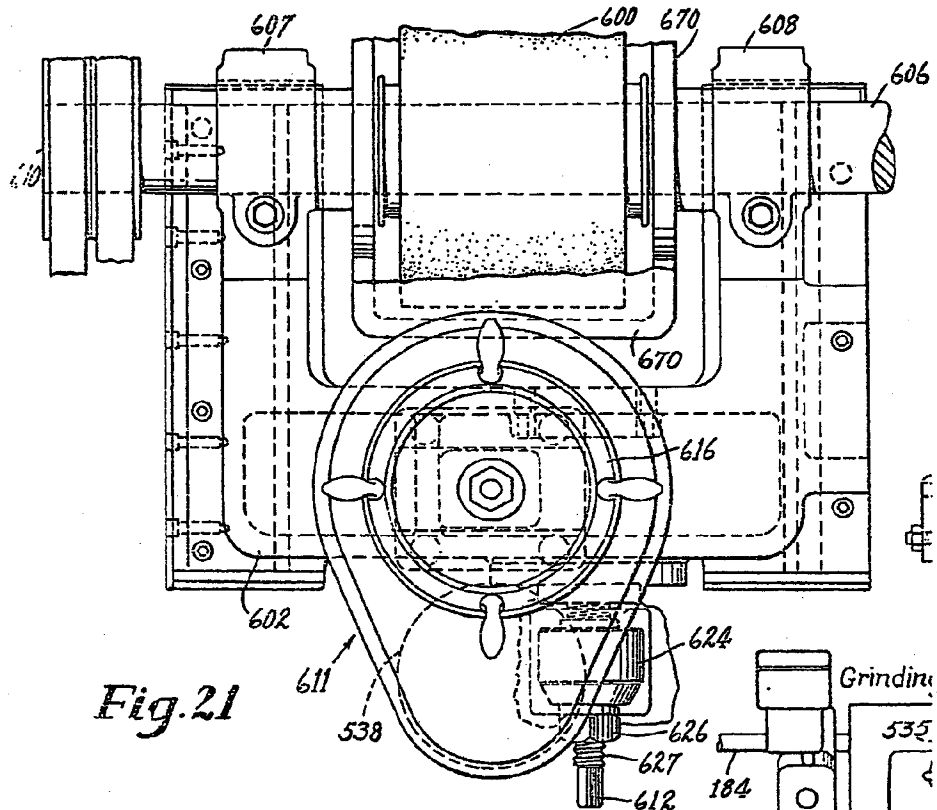
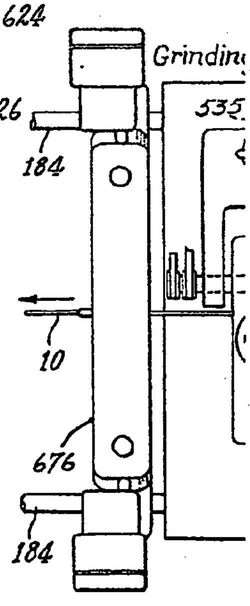
649
662
663
664
622
632
635
660
666
665
604
669
184

Fig. 20



607
600
670
608
606
602
616
670
611
538
624
626
627
612

Fig. 21



184
535
10
676
184

Fig. 23

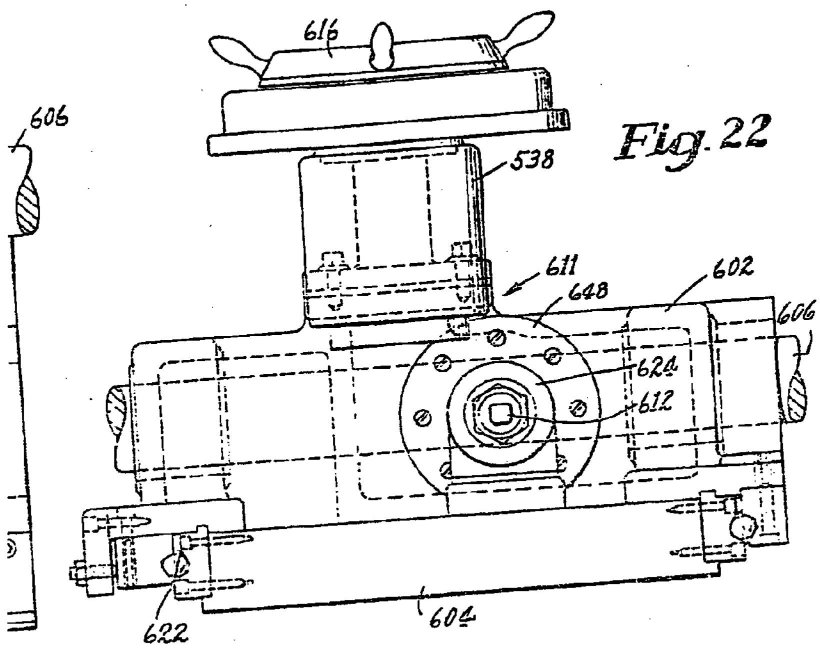
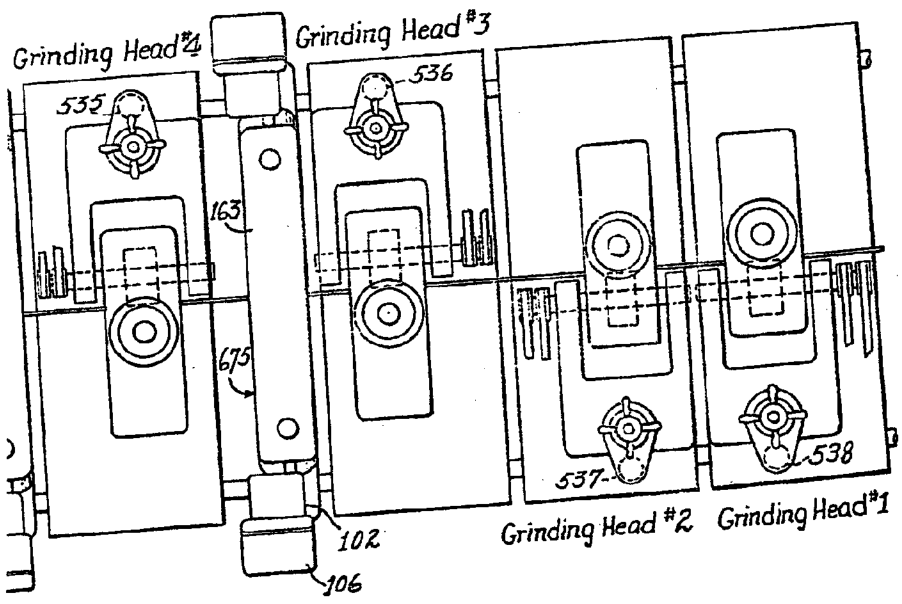

616
606
538
611
648
602
606
624
612
622
604

Fig. 22


Grinding Head #4
Grinding Head #3
535
536
163
675
537
538
102
106
Grinding Head #2
Grinding Head #1

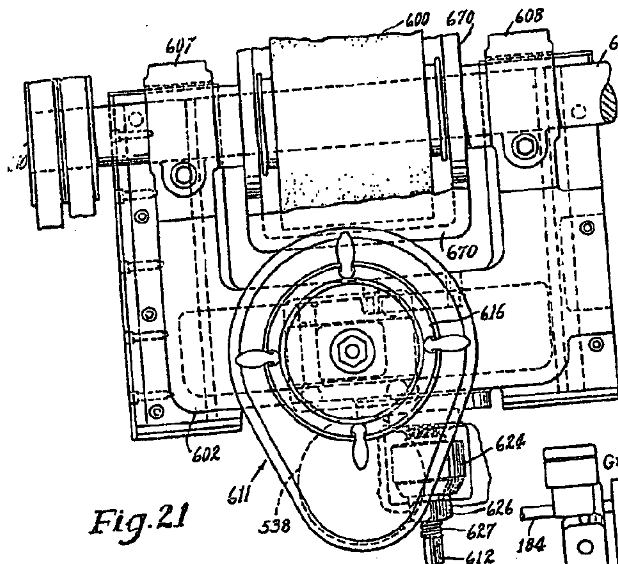


Fig. 21

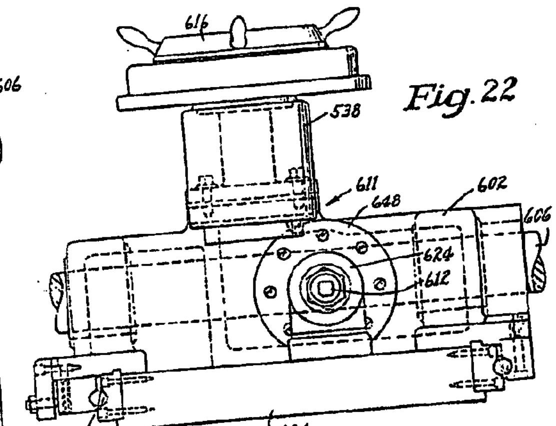


Fig. 22

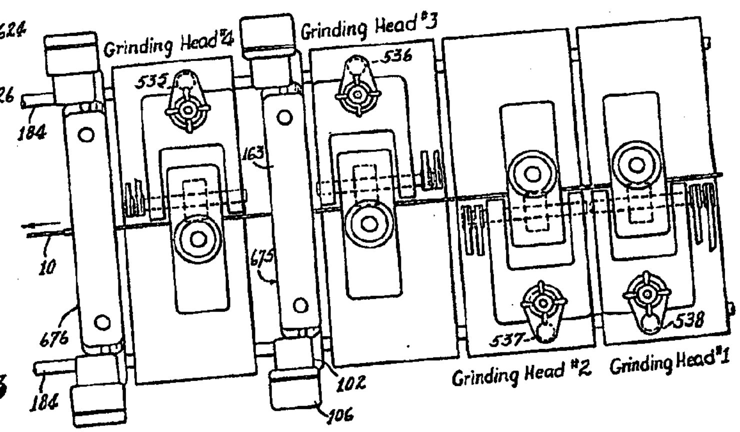


Fig. 23